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FEATURES

DEPARTMENTS

ABOUT THE COVER

The front cover is associated with an article on DOD's total quality management strategy to improve the processes used to produce defense materiel. The back cover highlights Army participation in the U.S./Federal Republic of Germany scientists and engineers exchange program.

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Total Quality Management

By Jack Strickland

Introduction

Our society is changing at an ever increasing pace due to advances in technology and the economic stimulation by foreign competition. America has historically been a leader in technology innovation, application, and productivity. This has provided us the competitive edge necessary to secure a large market share. A substantial loss of market share in recent years has been largely due to our failure to acknowledge and prepare for the increasing capabilities of our worldwide competitors.

The market for defense systems and equipment has been relatively shielded, but is now being affected by the increasing reliance on foreign manufacturers for various products that U.S. manufacturers can no longer produce with comparable quality at competitive prices.

Current economic conditions and the uncertain future being projected are compelling reasons for a change in attitude. Americans are awakening to the challenge of foreign competition, but find themselves in a mind-set that is very difficult to change. The industrial revolution and the post World War II prosperity gave everyone a false sense of security. A sustained demand for American products, sustained by a lack of competition in the international markets, induced complacency regarding quality and supported the pursuit of short term objectives for larger profit margins.

In many cases our profit techniques have relied mainly on quantitative measures based on macro economics, and have disregarded the impact of quality technology due to perceived excessive cost. Manufacturers are now being required to radically modify many of the ingrained concepts and adopt new principles based on the new concept that quality cannot be inspected into the end item.

Quality must be an integral part of the design and the manufacturing process. Quality does not cost, it pays. We need to change the culture, to which we are so accustomed, in order to achieve the necessary gains that will revive our manufacturing capabilities and improve our posture nationwide as well as

TWO VIEWS OF QUALITY

TRADITIONAL VIEW	CURRENT POSTURE
• Productivity and quality are conflicting goals.	• Productivity gains are achieved through quality improvements.
• Quality defined as conformance to specifications or standards.	• Quality is correctly defined requirements satisfying user needs.
• Quality measured by degree of nonconformance.	• Quality is measured by continuous process/product improvement and user satisfaction.
• Quality is achieved through intensive product inspection.	• Quality is determined by product design and is achieved by effective process controls.
• Some defects are allowed if product meets minimum quality standards.	• Defects are prevented through processes control techniques.
• Quality is a separate function and focused on evaluating production.	• Quality is a part of every function in all phases of the product life cycle.
• Workers are blamed for poor quality.	• Management is responsible for quality.
• Supplier relationships are short termed and cost oriented.	• Supplier relationships are long term and quality oriented.

worldwide. This change will not come easily, it will require long-term commitment, a massive re-education effort, some short-term sacrifices, and most of all, comprehensive planning and support from top level management.

During the past decade, we have witnessed a substantial loss of manufacturing capability as many companies and practically entire industry segments have closed shop. Failure to improve quality while striving to reduce costs and improve the declining profit margins caused by foreign competition has often been cited as the problem. Many companies have been driven out of the market due to their inability to recognize their shortcomings and implement fundamental changes throughout their organization. This process has, through the years, caused a significant erosion of our industrial base.

The ability of our military forces to meet our national security objectives is, in large measure, a function of the strength and vitality of U.S. Industry. If we characterize the condition of U.S. industry as a percent of the national product, it appears to be expanding. For example, factory capacity is increasing, capital investments are up, and unemployment is at its lowest level in seven years. However, these statistics are misleading because they do not reflect the true status of key defense industries. The DOD is dependent on many highly specialized industries; therefore, we must focus on specific industry segments when we assess the industrial base in relation to national interests.

The DOD has been surveying some industries known to be facing difficulties. We do not know the full extent of the implications of a failure of these highly specialized industries on our ability to preserve the peace or mobilize for war; but we do know that the DOD cannot solve industry's problems. Ultimately, industry's behavior will determine not only its own health, but also the national economy, and the future of the work force. However, we have concluded that the DOD can't afford to be complacent about the national security implications of a declining industrial base. We must, therefore, use the leverage of the DOD procurement budget to help modernize our factories, increase productivity and quality, and provide incentives that will promote technological and manufacturing leadership essential to national security.

Total Quality Management Approach

Total quality management is the application of methods and human resources to control the processes that produce our defense materiel, with the objective of achieving continuous improvement in quality. The DOD total quality management strategy also addresses the concurrent need to motivate U.S. industry to greater productivity. It is a strategy for improving the quality of DOD processes and products and achieving substantial reductions in the cost of ownership throughout the systems' life cycle.

The concept embraces the effective integration of existing management initiatives and initiation of new techniques that have a positive impact on quality. Examples are: acquisition streamlining, competition for quality, statistical process control and continuous process improvement, value engineering, transition from production to development, warranties, and gain sharing.

The concept of total quality management recognizes that quality extends well beyond the domain of the inspector, and that it must be an integral part of our system requirement, engineering and design, as well as the manufacturing process.

Within the DOD, quality has traditionally been defined as: "conformance to contractual requirements." This definition has been the crutch for fulfilling the legal requirements in the administration of contracts, while disclaiming responsibility for actual results. This often results in enforcement of contractual requirements regardless of their validity. Many contractors have been satisfied with short-term profits and neglected long-term consequences.

Recognizing that the designer and manufacturer, as well as the ultimate user of the products, have a key role in the quality equation, the DOD and a select number of industry associations have agreed on a new definition for quality: "Conformance to correctly defined requirements satisfying customer needs." This new definition doesn't in itself resolve the problems; it does, however, provide the correct perception of quality, which expands its domain throughout the product life cycle and involves everyone in implementation to assure success. The DOD Posture Statement on Quality captures the essence of the strategy. The accompanying chart compares the traditional view of quality with the current posture.

"Good enough" vs."Continuous Improvement"

The DOD uses product specification and standards to impose contractual requirements. These documents are essential to the acquisition process because they provide the baseline for the bidding process, as well as providing the legal basis to determine contractual compliance. One of the requirements found in these documents is Acceptable Quality Level (AQL) or the Lot Tolerance Percent Defective (LTPD).

These provisions were originally intended to institute standard sampling procedures to ensure quality integrity of large production lots. Such numerical values, however, have been used by many manufacturers to justify lack of action in instituting effective process controls to improve quality. These contractors have become complacent with the 'good enough for the government' concept, and lost sight of good business practices aimed at customer satisfaction and a lasting relationship based on integrity. Allowing a persistent level of errors as a way of life has contributed to unacceptable failure rates in defense equipment and to the escalating cost of maintenance and logistic support.

The DOD, to rectify the perception of allowable defects and stimulate changes to improve product quality, has recently directed its specification preparing activities to remove AQLs and LTPDs as fixed requirements in military product specifications. This action will provide opportunities to improve quality to the maximum extent possible by promoting competition based on excellence. In the past, quality effort emphasized final inspection to detect defects after they had been produced in order to determine compliance with the required AQL or LTPD.

Intricate sampling plans based on prescribed AQLs required the inspection of products to determine acceptance, thereby relieving the contractor of further responsibility for quality. The new approach recognizes the value of sampling inspection techniques as a quality assurance tool. It removes, however, the inference that a predetermined amount of defects is expected and allowable. It enforces the concept that all delivered products are expected to comply with the established technical requirements.

Contractors must institute effective

process controls and in-process inspection techniques that preclude out of tolerance conditions during manufacturing in order to achieve continuous improvement and be able to compete on the basis of quality. By stabilizing the process well within acceptable limits, the "defect-detection" approach is replaced with the "defect-prevention" technique. The latter does not leave the process to chance and then require screening of the good from the bad at the end of the process, nor does it rely exclusively on a sampling inspection that offers a measure of the degree of non-compliance.

What we are doing is to provide the basis for the ensuing changes that will dramatically affect the manufacturing processes. Once the concept of continuous improvement is understood, and management systems are designed to achieve implementation, there is no turning back; the process will drive itself towards the ultimate goal of continuous improvement and total defect-free outputs.

Statistical Process Control

One key element of the continuous quality improvement concept is process control. For most manufacturing processes, the statistical process control (SPC) technique is the most effective. SPC is based on the premise that all processes exhibit variation; in other words, it is an analytical technique for evaluating the processes and taking action based on stabilizing the process within the desired limits.

SPC is most effectively used as an operator's (production) tool. It assists the operator in making timely decisions about the process: adjust, leave alone, or shut-down and take corrective action before defects are produced. SPC provides evidence of how a process is performing. SPC helps distinguish between patterns of natural variation (expected), and the non-desirable, unexpected variations (assignable to a malfunction). SPC provides a better understanding of how the processes affect the products. Assurance of conformance is, therefore, obtained through defect prevention by control of the various processes, rather than after the fact inspection.

Overall Cost vs. profits

By putting quality in the proper perspective, we are able to formulate objectives and identify the proper actions required throughout the entire acquisition process. We have traditionally based profit policy on a percent of contractor cost. It makes perfect sense to formulate a contractor profit policy that promotes reduction of overall costs by rewarding the contractor's efforts with a share of the savings. The Gain-Sharing Program implements this concept by awarding the contractor a portion of the savings realized through his efforts in cost reduction while preserving high quality and performance.

Quality in the Source Selection Process

The procedures used to award contracts have traditionally been focused on the lowest bidder, among other factors, as the criteria for achieving the lowest procurement cost. This approach has been applauded for enhancing competition; however, quality has always been an afterthought, trusting that everyone would be able to produce quality products. To further compound the problem, past history of performance has not played a role in determining eligibility for future contract awards. In other words, contractors with poor performance history would continue to compete at an equal basis with contractors more capable of producing quality products and that have a good reputation in dealing with the government.

Recent changes to the Federal Acquisition Regulations make quality a factor in the source selection process. The intent here is not to exclude any potential bidder, but to raise quality con-

DOD POSTURE ON QUALITY

THE SECRETARY OF DEFENSE

WASHINGTON, THE DISTRICT OF COLUMBIA

DoD POSTURE ON QUALITY

- *Quality is absolutely vital to our defense, and requires a commitment to continuous improvement.*
- *A quality and productivity oriented Defense Industry with its underlying industrial base is the key to our ability to maintain a superior level of readiness.*
- *Improvements in quality provide an excellent return on investment and, therefore, must be pursued to achieve productivity gains.*
- *Technology, being one of our greatest assets, must be widely used to improve continuously the quality of Defense systems, equipments and services.*
- *Quality must be a key element of competition.*
- *Acquisition strategies must include requirements for continuous improvement of quality and reduced ownership costs.*
- *Managers and personnel at all levels must be held accountable for the quality of their efforts.*
- *Competent, dedicated employees make the greatest contributions to quality and productivity. They must be recognized and rewarded accordingly.*
- *Quality concepts must be ingrained throughout every organization with the proper training at each level, starting with top management.*
- *Principles of quality improvement must involve all personnel and products, including the generation of products in paper and data form.*
- *Sustained DoD wide emphasis and concern with respect to high quality and productivity must be an integral part of our daily activities.*

sciousness and to give extra consideration to those companies/suppliers with a good record and whose products and services reflect the application of continuous quality improvement techniques. Through this approach, the acquisition cost is placed in the proper perspective as related to the total cost of ownership throughout the product life cycle. The underlying objective is to consider quality as equal to cost and schedule.

Industrial Modernization Incentive Program

The Industrial Modernization Incentive Program is a major DOD initiative to foster long term modernization of the defense industrial base. The program objective is to increase defense contractors' capital investment in order to enhance productivity, improve quality, reduce acquisition costs, and expand the industrial base. Benefits can be measured in terms of increased manufacturing flexibility and production capacity able to respond to defense requirements, in addition, savings realized throughout the life of the more reliable weapon system produced in the modernized facilities.

Warranties

Much has been said about warranties in the context of providing assurance of quality. Warranties are used successfully in the commercial world, and they do present a good tool in our quest for quality. The commercial market, however, is much different from the defense market. The DOD does buy many commercial products with the same warranties enjoyed by the general public; however, the majority of purchases are for unique equipments and systems produced in small quantities. Moreover, these equipments are handled and serviced by government personnel, and considering the number of people involved, the complexity of the supply system, and the various performance requirements that cannot be readily tested, it becomes very difficult to effectively administer warranties.

From a quality perspective, the warranty concept is sound as long as it is not used as an insurance policy. The primary intent for using warranties should be to motivate contractors to improve the quality of their products, so that they would reap financial benefits by avoiding the warranty cost of repairs and replacements. Warranties are no substitute for quality, and should not be used as a crutch. Simply put, when a system fails to accomplish the mission for which it was intended, the warranty can never compensate for potentially devastating results.

Acquisition Streamlining

Acquisition streamlining is a major initiative directed at the development of realistic and cost effective contract requirements. The program objectives are to reduce the time and cost of weapon system acquisition, and to improve quality by ensuring that only the necessary requirements are imposed during each acquisition phase through tailoring of military standards. This approach gives program managers greater latitude to defer imposition of military specifications and other detailed "How To" contract requirements until industry has had the opportunity to recommend the most technically appropriate and cost effective approaches.

Efforts are underway to enhance streamlining policies to encourage early analysis and trade-offs to weapon system cost and performance, in order to achieve the best value for the DOD. The military departments and industry are working together to identify outdated and unnecessary military specifications and standards, and come up with better procurement documents that are compatible with new technology. A recent survey completed on 30 acquisition programs indicated that streamlining is resulting in significant reductions in lead time and cost of weapon system acquisition, as well as enhanced quality due to better understanding and timely imposition of requirements.

Value Engineering

Value engineering is a systematic effort directed at analyzing the function of systems, equipments, facilities, services, and supplies, to achieve essential functions at the lowest life-cycle cost without compromising the required performance, reliability, quality, and safety. Value engineering is also used to improve quality and reliability, thereby achieving additional long term benefits.

The DOD Value Engineering Program has two elements: one is the in-house activity performed by DOD personnel; the other is the DOD contractor program. Both elements have provided financial rewards. During the 1986 fiscal year, the in-house program yielded approximately one billion dollars in savings, while contractor proposals amounted to an additional saving of $450 million.

A New Beginning

Manufacturing, productivity, industrial base, and competitiveness improvements are intimately related to quality. These are areas vital in maintaining technological leadership and are critical to both the Department of Defense and the nation as a whole. They are also examples of where defense and national needs converge. If we are to achieve and sustain the technological and manufacturing capabilities essential to the security and economic well being of the nation, then it is clear that we can no longer afford to continue on the same old course.

A new breed of leaders is sorely needed in our management pool. The leaders we need must not only be knowledgeable of finances and marketing, but of technology and people as well. Those companies that are successfully making progress in revitalizing their businesses are aggressively reorganizing their management structure to promote new concepts and achieve quantum improvements in quality productivity by harnessing all the available resources toward common goals. These companies are making a true commitment to quality, and are relentlessly pursuing improvements.

Government and Industry must be resolute in a joint effort to make the transition a reality. We all have the obligation to promote stable and uniform policies that provide continuity. We must not become complacent. We must seek a renewal of pride in workmanship, at all levels, to instill the spirit of doing our jobs better. That is the essence of the pursuit of quality. Continuous quality improvement must be our goal. The well being of our future generations depends on it.

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Tapping Our Natural Resources. . .

Army Exchange Scientists and Engineers

By Margaret F. Smith

Introduction

1988 marks the 25th anniversary of the Department of Defense International Professional (Scientist and Engineer) Exchange Program with the Federal Republic of Germany. In April, the anniversary will be celebrated with a day-long event attended by high-ranking U.S. and German government officials, program administrators from Germany and from all three U.S. Services, and selected former and current exchange personnel, all of whom will gather to pay recognition to this program.

During the last 25 years, the U.S./German exchange program has produced more than 1,000 alumni, mostly German, but also U.S. personnel from each of the three Services. In the last decade there has been a marked increase in the number of Army "graduates." This article takes a look at the pioneers of the U.S. Army participation in the U.S./Federal Republic of Germany exchange program.

Participants

One way to look at the program is through statistics — 18 U.S. Army personnel, representing nine different major subordinate commands and research, development and engineering centers, assigned from 1980 to the present. A better way to examine the program is through the individuals who have participated in it, who have gained tremendous knowledge, experience and insight, and who represent a valuable, if untapped, natural resource to the U.S. Army. Who are these pioneers?

The very fist Army exchange engineer was J. Craig Allen, then from the Armament, Munitions and Chemical Command (AMCCOM) Product Assurance Directorate (PAD), who paved the way in 1980 with his assignment to the Weapons and Ammunition Technology Division of the German Office of Defense Technology and Procurement (BWB) in Koblenz. He was followed by Kenneth P. Yagrich, also from PAD, and also to the Weapons and Ammunition Technology Division of the BWB.

In 1982, the Chemical Research, Development and Engineering Center (CRDEC) began its active participation in the exchange program by sending its first engineer, Michael S. Ford, to the German Federal Armed Forces Science Agency for NBC Protection in Munster.

In 1983 and 1984, both PAD and CRDEC continued to provide the Army's exchange personnel by sending a new engineer for every returning engineer. John P. Thies and John P. Corsello followed from PAD, and Joseph W. Hovanec from CRDEC.

In 1985, the pattern was broken, with the Ballistic Research Laboratory (BRL) and the Tank-Automotive Command (TACOM) joining the program. BRL sent its first scientist, Dr. Joseph M. Heimerl, to the Ballistic Division of the Fraunhofer Institut fuer Kurzzeitdynamik, Ernst Mach Institut, in Weil am Rhein, and TACOM sent its first engineer, Dr. Roger A. Wehage to the Industrieanlagen Betriebsgesellschaft (IABG) in Ottobrunn/Munich. Throughout 1985, PAD and CRDEC rotated their engineers again, sending August W. Thiesing and Mark L.G. Althouse to the BWB and to Munster respectively.

In 1986, the program expanded even further throughout the Army Materiel Command (AMC) community. The Armament Research, Development and Engineering Center (ARDEC), sent its first engineer, Susan Dickerson, to the Weapons and Ammunition Technology Division of the BWB, and TACOM sponsored the first Army officer in the exchange program, CPT James R. Moran, who was assigned to the IABG in Lichtenau. BRL became a recurring participant by sending Dr. Pamela J. Duff to the Fraunhofer Institute in Karlsruhe.

All of the individuals named above are now back in the United States. Five individuals are currently on assignment in Germany. They are Wolfgang Fischer, from the Communications-Electronics Command (CECOM), assigned to the Communications Technology and Electronics Division of the BWB; Dr. Donald E. Snider, from the Atmospheric Sciences Laboratory (ASL), assigned to the Weapons and Ammunition Technology Division of the BWB; Lawrence M. McCormack, from CRDEC, assigned to Munster; George D. Quinn, from the Materials Technology Laboratory, assigned to the German Aerospace Research Establishment (DFVLR) in Porz-Wahn/Cologne; and Richard A. Hayes, from the Test and Evaluation Command (TECOM), assigned to German Federal Armed Forces Technical Center for Explosives and Special Technology in Oberjettenberg.

The mechanics of the exchange program are described in Army Regulation AR 70-58, International Professional (Scientist and Engineer) Exchange Program, which is being revised and incorporated into AR 70-41, International Cooperative Research and Development, and in a recent HQ, AMC (AMCICP-CR) supplemental memorandum, dated Nov. 12, 1987, which was widely distributed throughout the Army.

The latter estimates the cost of par-

ticipation to be approximately "$120,000.00 to $150,000.00 for one employee with family for one year" . . . which covers "salary, PCS move for family, and TDY within host country." This represents a serious investment on the part of the sponsoring parent command, and as can be expected, there is quite often a reluctance to make this investment. As Mike Ford comments, "There are managers who see the program as a loss of an employee for a year or more, still being paid his/her salary but producing no immediate results for the sponsoring organization," but as he goes on to write, "this attitude ignores the long-term benefit to the Army."

Return on Investment

An often heard phrase these days is "return on the investment." Although some of the former exchange personnel have gone on to jobs in other AMC or MACOM organizations (four of the 13, to be exact), all of them — without exception — still work for the Army. And all of them are examples of the return on the Army's investment.

Let me give you just a sampling of the immediate return realized from such an exchange assignment. One type of return is in the form of results from cooperative research. To illustrate this, let me quote Dr. Heimerl.

"One very important aspect of my tour . . . was the formulation, development and experimental testing of a hypothesis that explains the functional mechanism of secondary flash ignition . . . The conception of this hypothesis and its subsequent verification would probably not have happened without the strong, daily interaction between Klingenberg (his German colleague) and myself. The ideas were initiated, formulated and developed over a period of about three months. This kind of intense application to a particular topic just does not happen on a 5-day TDY tour. The time frame (of over a year in my case) was sufficient not only to get the idea, but also to design the experimental tests and partially carry them out . . . This novel idea will fundamentally change the way in which the muzzle flash is thought about and sets the tone of future research in modeling and experiments in this field for years to come."

Another type of immediate return is in the form of familiarity with German equipment identified for evaluation under the Army's Foreign Weapon Evaluation Program, International Materiel Evaluation. Mike Ford writes, "Projects which have a German connection, such as our evaluations of the German decontaminating emulsion or the German Army's (NBC) reconnaissance system are now not unfamiliar to us, and we can do a better job of spending the Army's test money than we could starting from scratch."

And yet another type of return is in the form of observations on better ways of doing business. Sue Dickerson, whose primary involvement was with the test and evaluation of the German MUSPA (multi-fragment passive) mine, took her impressions on testing procedures back to ARDEC. "The Germans are ahead of us in the area of testing by simulation. They have taken advantage of the fact that modern munitions are composed of electronic sensors which are triggered by various signature sources. These simulators provide signatures from their data banks which are continuously available. Use of these simulators has been able to save time, money, and resources in the testing of developmental and production items."

The list goes on and ranges from development and utilization of common computer modeling programs, proposals for work sharing in the development of low vulnerability ammunition, hands-on experience with established interoperability programs, to identification of potential nondevelopmental item acquisition candidates. These are the tangible results, the easy way to illustrate return on the investment. But there is also a more intangible long-range return which each of the exchange personnel has to offer.

Feedback

Each exchange scientist/engineer begins his or her assignment with a detailed work plan prepared by the host organization and agreed to by the parent organization, but often it is the unplanned effect of personal involvement and personal initiative which provides the long-term payoff. Some of the former exchange personnel polled for this article have tried to put this effect into words. They state it in different ways, but come up with essentially the same conclusions.

Joe Heimerl writes, "For the most part I have discussed those unplanned events that happen. These kinds of connections are tenuous, unpredictable and can be leveraged (in the sense that the amount of time invested can reap a continuing return to both the parent agency and the Army throughout the remainder of the exchangee's career). I am convinced that they can have more influence on the course of technical evolution and have longer lasting, intangible benefits to the BRL and to the Army (say, simply through increased and more accurate communications) than the planned technical program of the exchange."

Mike Ford notes, "Our European allies look at defense problems differently than we; necessarily so since the projected battlefield is on their soil. So we can also benefit from the advantage of having a problem of common interest viewed from a different perspective . . . In other words, the two organizations approach the solution from two different directions by two different schools of thought. Chances are that by doing so, one of us has found a better or more efficient way of accomplishing the goal than the other . . . Many re-inventions of the wheel can be prevented by merely . . . seeing first-hand how they do it. Having a scientist on-site during a research project of interest to both organizations is an invaluable link; one can read the results of an experiment in the final report, but the problem-solving techniques and test facilities are often not described in such a report, and can only be truly understood by being there."

Sue Dickerson probably sums it up for all the former exchange personnel by stating, "The scientist/engineer becomes intimately familiar with (the German) way of thinking, administration of defense programs, and organization of the defense system. Because of this, he or she is extremely qualified to deal competently with the Germans on bilateral and multilateral programs, primarily because the initial step of achieving mutual understanding . . . has already been accomplished. It is true that the Germans understand the organization and operation of our defense system, but it is still uncommon, although no less important, that we Americans understand our bilateral partner equally as well. Even though we are the leading nation in most of our bi- and multilateral programs, we should not fail to stress the importance of knowing and understanding our cooperative partner(s)."

The question now is whether the Army is taking full advantage of these natural resources. The alumni are logical candidates for active participation in bi- and multilateral cooperative pro-

grams, but not all of them being employed in this role. Only one of them has been named as an associate technical project officer on a Data Exchange Annex with Germany. Some of them have changed jobs to be able to work on international projects in which they can build on their experiences. Some of them continue to follow-up on their own initiative. An example is Dr. Heimerl, who is co-authoring, with his former German colleague, a monograph on their research into muzzle flash and its chemical suppression.

CPT Moran, who has been assigned to the Army Space Command, assesses the situation as follows. "Naturally the full benefits of a military officer's contribution is realized in the follow-on assignments. There are many Army programs, some major, which involve foreign governments. An officer with international experience could be a valuable resource to these cooperative programs . . . This brings up a challenge . . . how does the Army take advantage of the experience of these officers?" This is a valid question for the civilian participants as well.

Increased Attention

The exchange program has received increased attention in the last few years, in the form of publicity, in the form of AMC recognition, and, most importantly, in the form of increased numbers of participants from a broader spectrum of the Army community. From every individual who has participated in the program, we have learned how to improve its administration, and we will certainly continue to fine tune the programmatic aspects to enhance the benefits of the exchange experience for the individual and the Army.

In his article, "Windows of Opportunity . . . International Armaments Cooperation," which appeared in the November-December 1986 issue of *Army RD&A Magazine,* Bryant R. Dunetz identified the exchange program as one of the windows of opportunity in the context of the new shortened acquisition process. The opportunity is there to be seized, and more importantly, the resources represented by the 18 pioneers highlighted here, and those who follow after them, are there to be tapped and fully utilized by the U.S. Army.

Let me end this article with the words of some of the former exchange personnel. "The program is excellent, and I cannot understand why there is no long waiting list." "The scientist and engineer exchange program should be embraced by all Army R&D organizations; there is much to be gained at very little cost." "I hope that our Army will recognize the importance of this program and that it will appropriately utilize the experience that can be furnished by the exchange scientists and engineers." The words speak for themselves.

NOTE: In addition to the program with the Federal Republic of Germany, there are also programs with Egypt, France, Israel, Korea, Norway, Pakistan and the UK. Program MOUs are pending with Australia, Canada and Spain, and other countries under consideration for agreements in the future include Belgium, Brazil, the Netherlands, Sweden and Turkey. Interested candidates should contact HQ, AMC (AMCICP-CR, John O'Brien, AV 284-3218) for information.

MAGGIE SMITH is currently the AMC liaison to the BWB. She holds an M.A. from the Monterey Institute of International Studies and has worked in AMC international cooperative programs since 1982.

Application of ILS Lessons Learned

The Army Integrated Logistic Support (ILS) Lessons Learned Program was established in 1980 as a means of collecting and disseminating data on experiences gained throughout the ILS community, and to help avoid recurring and costly problems.

The lessons learned program was established under the authority of AR 700-127, ILS. The Army Materiel Command's Materiel Readiness Support Activity (MRSA) is responsible for maintaining the program.

Realizing the ILS lessons learned data base was continuously growing, but not necessarily being taken full advantage of, MRSA began providing tailored "push packages" to program managers approaching critical events. Recipients of the push packages are selected based on schedules contained in the Acquisition Management Milestone System, also maintained at MRSA. Titles of available push packages and their applications are: ILS Management (Program Initiation), Contractual Requirements (Release of Any Solicitation Document), ILS Testing (Start of Logistic Demonstration), Provisioning (Provisioning Planning Conference), and Materiel Fielding (Forwarding Draft Materiel Fielding Plan).

Push packages contain all lessons available pertaining to their respective subject. New information is added as it is received through the lessons learned collection process. Existing lessons are reviewed periodically for currency and applicability.

MRSA also provides tailored reports to customers upon request. These products focus on one or more elements of ILS, the five topics addressed above, Logistic Support Analysis/Logistic Support Analysis Record, nondevelopmental items, and product improvement.

Requests for tailored reports, additional information on the lessons learned program, or products of the program should be forwarded to: Commander, USAMC Materiel Readiness Support Activity, ATTN: AMXMD-EI, Lexington, KY 40511-5101.

Interview With GEN Louis C. Wagner, Jr.

Commanding General, U.S. Army Materiel Command

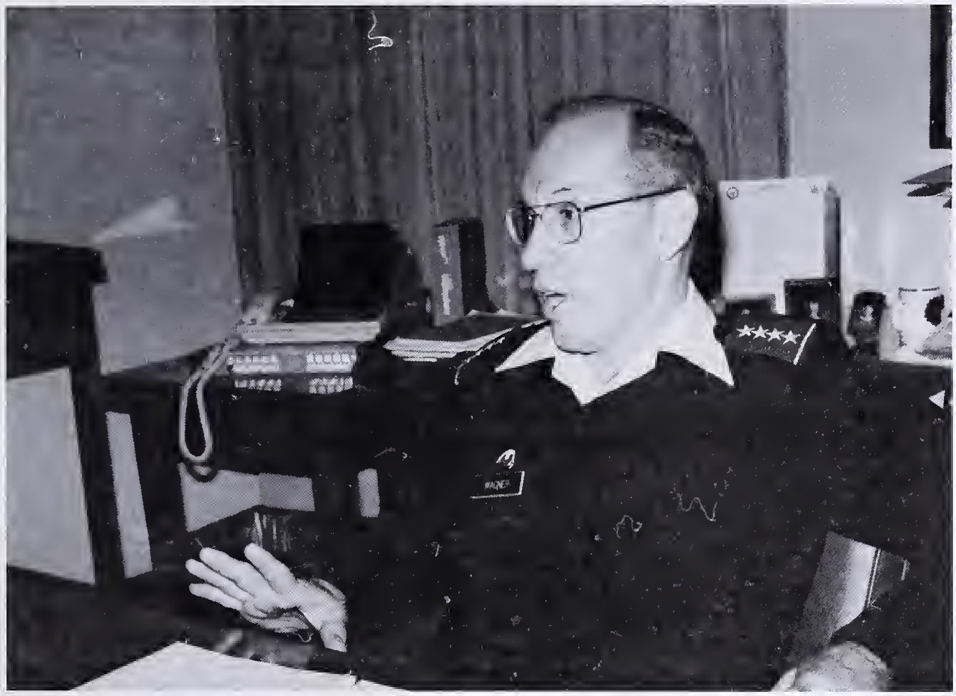
Q. ***Almost without exception, every new CG has an agenda for improving the way his command conducts business. What types of improvement initiatives do you have on your agenda for AMC?***

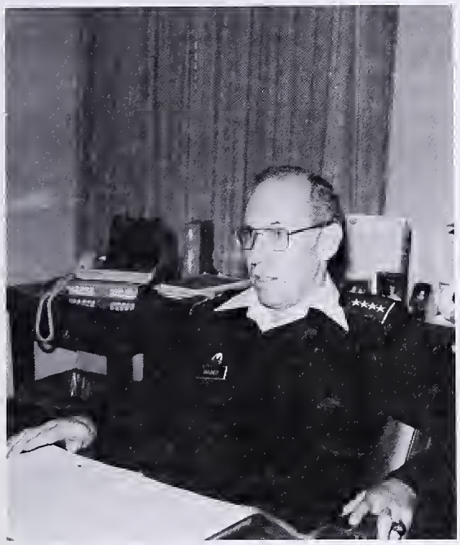
A. First of all, I don't believe that it's ever necessary, or at least rarely necessary, for a new commander to come in and totally reorganize a command. So I have no intent to reorganize AMC. There will be evolutionary changes that we'll make to improve the way we do business. I think that is absolutely necessary because as missions and organizations change — and there are major organizational changes going on at the DA staff level and with the PEO and PM concepts — we have to make changes to go along with these. Basically, what I tell my people, and I believe this very strongly, is that our primary mission is to support the soldier and everything we do has to be oriented towards that.

I think we need to become more proactive. Sometimes organizations have a tendency to be defensive in nature and over react to criticisms and problems. We need to anticipate these ahead of time. Incidentally, as I go around the Army Materiel Command I think people are being proactive, but I think we can get better at it.

I specifically want to improve the image of the Army Materiel Command. Unfortunately, within the Army there is a "we/they" syndrome between the supporter and the fighter. This is bad because our joint mission is to deter war, and if war comes, to win that war. We are the individuals who provide the equipment and support to the soldier on the line to win that war, so we need to get rid of the syndrome and understand that we are a "single Army." I also want to improve the efficiency of AMC because we are not going to get more people. Since AMC was formed in 1962, we have gone from 189,000 to about 120,000 personnel. At the same time, however, the workload has increased, if you consider such things as the number of requisitions we process — which is approximately five million a year — or if you look at the number of line items that we stock and handle for the field — which is between four and five hundred thousand. If you look at those factors, the workload is coming up.

One way of improving efficiency is to make better use of automation. The Army, like the civilian world in general, has used the computer only in automating the old manual systems. In other words, they have not removed steps or forms in the process. They have merely put these on a machine. In my view, that is a poor use of automation. We are looking at ways of streamlining the entire logistical support process for the Army. I am not going to "throw out the baby with the bathwater," however, and throw away a system which is working before we know we can improve it. In fact, we have several experiments going on right now to see how we can improve total logistical support. I would like to point out that we are working very closely with the Training and Doctrine Command (TRADOC) to do that because the doctrinaires for determining how we are going to support the Army are found at the Army Logistics Center. We are going to work very closely with them to do a better job.





Q. ***How would you describe your management philosophy?***

A. First of all, a leader must use his subordinates properly. I believe strongly in delegation of authority to subordinates. We select great leaders for the jobs as my deputies, for the deputy chiefs of staffs at AMC Headquarters and for the commanders of the major AMC organizations located away from this headquarters. They have to be allowed to perform their jobs and I allow them to do that. I give them general guidance and they perform their jobs. If I have a problem with them then I correct it because the second function that any commander must perform is to mentor and train his subordinates. I am not an individual who believes in establishing a set number of goals. For example, I don't believe in establishing five or 10 goals that everyone puts on a poster and places beside or on their desk to look at every day to be sure they are carrying out those goals. The reason I don't do that is because I found in my own experience that subordinates concentrate only on those areas and overlook many other areas that are very necessary to the normal and proper functioning of an organization. I have recently published a "White Paper" which outlines my general philosophy and what I want to see happen in the Army Materiel Command during by tenure. It outlines what I believe must happen as we go into the next century to properly support the Army in the field.

Q. ***Some individuals have expressed mixed reactions to the Program Executive Officer/PMs reorganization. What is your assessment?***

A. As you know the Packard Commission recommendations were designed to eliminate layering that they perceived in the acquisition process. In other words, they said that a project manager, in a sequential fashion, had to go through many layers before he ever got up to any individual in the Department of the Army or Department of Defense who could make a final decision on his program. As a result, the program became diluted and a lot of extra time was spent on getting it through all of that layering. I don't agree with that perception in general because I saw it in some cases, but didn't see it in the majority of the Army's programs. However, we have complied with the Packard Commission Report in forming the Program Executive Officer (PEO) group in the Army and the PMs to serve under them. The key principle that we are stressing very strongly in the Army Materiel Command is that there is a partnership between AMC, particularly at the major subordinate command level, and the Program Executive Officers. This partnership is designed to insure that we work as a team to come up with the best possible program, and to do it as effectively and quickly as possible. There's no way that a PEO or a PM could ever field a major item of equipment without support from the Army Materiel Command. We provide that fielding support and must be on the front end of the program to make sure it's all available when the PEO or PM gets ready to field a piece of equipment. It would be a waste of resources to fully man every single position in a PM's shop that he might have a need for on a weekly or less frequent basis. We will be providing matrix support to the PMs in helping them do their common tasks, such as legal, finance and all of those other support functions they need. They will have a minimal staff that will provide the leadership for the program, the direction of the program, and then come to the MSC commander for the additional support they need.

There is a major change in the way we are doing business at AMC Headquarters. Since we are no longer directly in the chain-of-command of the PM, but do have many of the Army's real experts in the budgeting and programmatics that are essential to a PM's program, we are sending those people out to the field to assist the PEOs and PMs during the initial formulation of their programs. They will assure that the program is put together properly and makes sense, rather than being the graders as it comes through this headquarters. In the long term, I think this will have a payoff because we will train the people down in the trenches — those men and women who have been putting programs together — how to do their job better so that we will find less errors and problems in them when they are presented to the Army Acquisition Executive for a final decision. The key point is that we are partners and we do that all the way. I think there will be

changes in the PEO/PM/AMC relationship as we learn more about how to do business. The Army Acquisition Executive, Mr. Ambrose, and I have discussed this on a number of occasions and he agrees that we are organized in the best manner possible right now, but we are going to watch it carefully and make changes as necessary to improve the way we do business.

Q. *What impact, if any, will the reorganization have on AMC's efforts relative to the streamlined acquisition process?*

A. I don't think it will have any real major impact on it because the streamlined acquisition process is an attitude and a state of mind as much as it is a major change in the procedures for doing business. Even before the PEO/PM system was put into effect, it was Army policy for us to do the front end work better and to cut out sequential reviews. In other words, you don't have a separate meeting with every individual involved in the process, but everyone meets at the same time and scrubs the program to make sure it's straight before it goes forward. You are going to see this continuing under the PEO/PM process. We are also reducing the number of military specifications down to the bare minimum to get the product we need in the field. Shortening up Request for Proposal (RFP) for the T800 turbine engine was a good example of this. This isn't going to change under the new system. We are continuing to work very closely with TRADOC to make sure that the requirements in the Required Operational Capability make sense, can be achieved and can be translated into an RFP for industry that can be met. That is part of streamlining.

Finally, where possible, we will buy off-the-shelf nondevelopmental items which may come from the commercial market or may have been designed and fielded by allied armies. This approach can save us money and time in providing equipment to our soldiers. The bottom line is that the PEO system and streamlined acquisition will really have a synergistic effect on improvement of the acquisition process in general.

Q. *During the most recent Atlanta Executive Conference, there was some lively debate on whether defense contractors should be reimbursed for special tools and equipment costs incurred during the development and production stages of the acquisition process. What are your thoughts on this issue?*

A. I was present at that meeting and to say that it was lively is probably an understatement. It was vehement at times. First of all, they will be reimbursed. There is no question on that. It is the timing of the reimbursement that they have a problem with. Formerly, they could be reimbursed 100 percent for the special tooling and special test equipment with the current contract. For FY 87 contracts, they can receive up to 50 percent of that reimbursement in each fiscal year with the balance spread over future contracts. This caused industry problems as, in some cases, it takes large outlays up front on their part which then would have to be amortized over many years in future contracts. Congress changed the rules in the FY 88 Act, so now industry will be reimbursed at a mutually agreed upon amount in the first year. However, the final policy still needs to be published. I think we do have to look at this carefully because we cannot expect industry to spend large amounts of money unless they make a sufficient profit and are able to use that. If not, it's going to come out of some other area. They will probably take it out of their research base and things of that nature, which are also very important to the Department of the Army and the Defense Department in general. We are going to continue to work with industry and the Congress to come up with what we think is fair and equitable to both sides.

Q. *How do you propose to deal with the ever increasing requirement to develop more and better weapons systems in the current and projected environment of decreasing resources to develop these systems?*

A. I suppose this question is more applicable now than it might have been a month or two ago because of the substantial reductions that are being considered in our programs in order to balance the deficit that we have in this country. I am not as pessimistic as most however. I don't think the sky is falling. We are going to have to tighten our belts. There is no question on that. There will be systems that we will have to kill and there will be systems that we will have to slow down production on. This means we will not modernize our Army as quickly as we would like to do. However, I want to also point out that during the last five years we have done more to modernize our Army than any time in the over 30 years that I have been in the Army. When you go out to see the Army today — in those units that have been modernized — it's the most effective, best trained Army that we have ever had. Unfortunately, we are only half-way there. So we are going to have to get smarter about how we do business. We are going to have to be tougher on the requirements side and make absolutely sure that any program that we decide to go forward with has a specific payoff on the battlefield so that we get the most balanced force possible.

We are going to have to look more at product improvement rather than coming up with a new product; that is, when product improvement will give us at least a mimimum required capability on the battlefield. We need to continue the policy that we've had in the past to make sure that we don't write requirements in order to get the last two to three percent performance that will cost an exorbitant amount of dollars. In other words, maybe the 80 or 90 percent solution will give us so much additional effectiveness on the battlefield, at an affordable cost, that it is the way to go instead of holding out for the ultimate solution.

As I pointed out earlier, we have to look more at buying off-the-shelf commercially and from other governments. Incidentally, our allies have the same problem. They are not going to have great increases in their defense budgets in the years ahead. So, we have to work very closely with them just as with the other Services in the United States so that we don't duplicate effort. With regard to that last point, we are working very closely with the other Services — the Air Force, the Navy, the Marines — to assure that we don't duplicate effort unless it makes sense to do so. In some cases it does make sense because there are alternative approaches to the solving of any problem.

Q. *During the past several years, there has been some substantial criticism in the public media of the Army's materiel testing procedures. What is your response to this criticism?*

A. First of all I wouldn't say that we should not have been criti-

cized in some respects. This is because it's possible that we should have anticipated some of the problems and possibly have done more testing. However, I'd also say that it's always easier to be the "Monday morning quarterback" than it is to have thought of every possible detail during the initial testing. I was a tester at one time in the Test and Evaluation Command (TECOM) of the old AMC before it became DARCOM and then AMC again. That was at a time when TECOM was responsible for both operational and development testing. That changed in the 70s and we are primarily responsible for development testing today. Most of the criticism has been of operational testing, which we are not directly responsible for. However, we have had our share of criticism of development testing too.

We are improving the way we test. We are training our testers better today and, probably more important, we have a concerted effort in the Army to commit the funds for the instrumentation that's necessary to do testing properly. There is always a tendency, when dollars are short, to cut the funds for the instrumentation for testing. This is because instrumentation is not something you are going to see on the battlefield. But if we are going to test properly we just have to spend those dollars, and I can tell you it involves hundreds of millions of dollars. It's not cheap, but in the long run I think it will help us turn out a better product.

We also have to get smarter about how we use a combination of actual physical testing and then analytical approaches using computer models to determine what we can expect from the item on the battlefield. There is no hesitancy on the part of Army leadership to test our equipment. In some cases, it's just that we probably haven't fully understood the complexity of testing properly. We will continue to improve that and assure that fielded equipment is the best possible that we and U.S. industry can provide to the soldier.

Q. ***In a keynote presentation at the 15th Army Science Conference, you emphasized the need for the Army's in-house laboratory community to establish a strong partnership with their peers in academia, federally funded R&D centers, and with industry. What specific initiatives have been undertaken to achieve this?***

A. As a preface, there is a tendency in any organization, and not just the Army laboratory system, to have the "NIH" or "not invented here" attitude. We have some outstanding scientists and engineers in our laboratory system who are doing great work. On the other hand, there are many scientists and engineers in the organizations that you just mentioned that can also do great work for the Army and we need to take advantage of that capability.

We have contracts with over 200 colleges and universities that are doing work for us today and we recently established 11 university research initiative centers of excellence which will concentrate in particular areas of science that we think will have a military payoff. We are making better use of the independent research and development (IR&D) programs of industry. A major study of our total IR&D program was conducted within the last year to make sure that industry was concentrating in those areas that we thought would have a high payoff on the battlefield. We are going to put more emphasis on encouraging industry to participate in programs that were not properly covered previously.

Finally, we are establishing a close working relationship with the Department of Energy (DOE) laboratories. In fact, very recently Mr. Ambrose, GEN Thurman from TRADOC, and I met with three of the principal laboratory directors of the DOE to determine how we could more effectively use their tremendous capabilities, particularly in analytical work and computer technology, to do a better job in developments for the Army.

Also, we have opened dialogues and have working groups with some foreign countries. The bottom line of this question is that we must have a strong Army laboratory system but we should also utilize every available resource from other facilities to make sure that we are developing the technology that will give us the payoff on the battlefield of the future.

Q. ***Since the ultimate goal of AMC is to provide effective and dependable equipment for the soldier in the field, do you believe there would be some benefit in stationing a senior enlisted individual at Army labs and RDE centers in order to get their input during the development process?***

A. In most cases we do have senior non-commissioned officers at the majority of our labs or some who frequently visit our labs. However, the bottom line is yes; we need to have a greater user input into all aspects of the development of materiel, from the tech base right through full-scale engineering development to fielding. The non-commissioned officers I would want in those positions would be those that have just come from field assignments in Europe, Fort Hood, or Korea for example where they have the latest knowledge of how equipment is used in the field, what the deficiencies are, and what the soldier is interested in. They could then help us with our MANPRINT effort to make sure we design equipment so it is user friendly when it finally gets out to the field.

Q. ***What areas of technology do you believe offer the greatest potential for advancing Army capabilities during the next decade?***

A. That's a tough one because there are so many areas of technology that can have a high payoff on the battlefield. It is hard to pick only a few. However, I'd say probably two of the highest payoffs could be in the signal processing area and the reconnaissance surveillance and target acquisition area in such things as photonics, acoustics, and microelectronics.

I am not saying there are not other areas such as electromagnetic propulsion, electrothermal propulsion and a better understanding of the use of lasers on the battlefield. But if we have a deficiency today, it's probably in the capability of our signal processing to take massive amounts of information from sensors and reduce it to a product that the soldier can use to destroy the enemy on the battlefield. For example, we now have tremendous sensors on the drawing boards for locating the enemy, but unfortunately when all of this data comes into the machinery that has to kill him — whether it's a helicopter or a tank — it is almost a manual operation for the commander or the pilot to process all that information and determine the value of the target and kill it. We are working on what we call Aided Target Recognition which will help us solve that problem. This effort will involve all of the areas that I have mentioned and will give us the effectiveness and time sensitivity we need.

***Q.** How do we draw the line between supporting basic technological research in our labs and research centers and support for specific weapon systems?*

A. Basic technology refers to those things I just talked about. It is generally defined as being non-system specific. In other words it has application to many systems on the battlefield. Numerically, it is referred to as 6.1, 6.2, and 6.3a efforts. This could even result in technology test bed demonstrators. Several of these could be put together and they may look like something that would be on the battlefield, but it would not necessarily be a final design that would be ready to go into full-scale engineering development.

Beyond the technology base we go into advanced development which is 6.3b. This is when we actually start developing a system that would be fielded on the battlefield and integrates, for example, the propulsion, the suspension, or a gun if it was a tank. Then we go into the final design — which is full-scale engineering development or 6.4. There is a fuzzy line, at times, between the non-system specific tech base and when you really go into advanced development. So, I can't get too excited whether it's sometimes called 6.3a or 6.3b.

We need to make very sure, before we ever go into advanced development or full-scale engineering development, that we have analyzed what the principal technologies are that must be integrated into that system and whether they are ready to go into system specific engineering. The best example of a system we are currently bringing forward properly is the LHX Helicopter. We have spent a lot of time, a lot of effort, and a lot of dollars on this program in doing the technology work up front to make sure that when we get ready to go into the demonstration/validation phase, and eventually into full-scale engineering, that we have a handle on the technology necessary for that job.

***Q.** Do you have any additional comments regarding AMC in general?*

A. Yes. In the eight months I have been commanding the Army Materiel Command, I have been on the road about 60 percent of the time. The reason for this is because I want to assure that what the command is doing is properly directed toward support of the soldier on the battlefield. In all of my travels, while I see things I might do different and make recommendations in that regard, I have also been very impressed and excited about the great number of dedicated individuals — civilian and military — who spend their lives supporting our Army. I have never seen a more dedicated group of individuals in any organization I have served in. We will continue to work harder to become more efficient in doing that job even better as the current belt tightening process takes effect.

Army Fields Mobile Subscriber Equipment

The largest fielding effort in the history of the U.S. Army began in February. During the following 5-year period, more than 272,000 items of Mobile Subscriber Equipment (MSE) will be provided to 2,500 Army units located throughout the world. The equipment will become the crucial tactical telephone communication system for the Army.

The First Cavalry Division, Fort Hood, TX, is the first to receive the new equipment. It has a secure voice and data capability, and includes hard wired equipment similar to an office phone, and mobile telephones similar to cellular car phones.

While on manuevers, soldiers check equipment to ensure that it is in good working order before firing it up.

The prime contractor for the entire project and the fielding effort, GTE, Needham, MA, won the competitive $4.3 billion contract in January 1984.

Under the total package unit materiel fielding concept, the Army Communications-Electronics Command and GTE will provide modern, up-to-date communications equipment to the Army, Army Reserve and the National Guard.

"Never before has the Army established a plan for fielding all units with the same equipment in this short time span," said LTC Edward Carnes, assistant project manager for MSE fielding.

COL John Power, MSE project manager, is responsible for overall management of the entire program. With him, more than 125 Fort Monmouth employees are directly contributing to the massive fielding effort.

MSE was purchased using a nondevelopmental approach utilizing existing hardware and software. By doing this, the Army avoided spending any research and development money, and saved years of testing time.

In past fielding practices, the Army would buy separate pieces and assemble them at a central location. Equipment would be replaced selectively to spread the new equipment out to soldiers who needed it most. Usually the Army Reserve and National Guard would get the older equipment that was replaced by new equipment in active Army units.

The Army would then be responsible for training and solving any problems with the mechanics of the assembly. With the MSE total package fielding, GTE is responsible for providing the whole working MSE System to one corps at a time.

At the fielding site, the equipment is readied and tested in a staging area to be sure it is working properly. Soldiers are then trained in portable classrooms. The equipment is inspected one last time and then signed over to the Army, at which time GTE's fielding responsibility is completed

The Army Reserve and National Guard are receiving MSE concurrently with the regular Army.

Dispelling the Myths of Test and Evaluation

By Dr. H. Steven Kimmel

**Assistant Deputy Director
Defense Research and Engineering
(Test and Evaluation)**

Test and evaluation is recognized as a key element of the weapon system process. By both long-standing practice and directive, weapon system test and evaluation is divided into two principal categories — Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E).

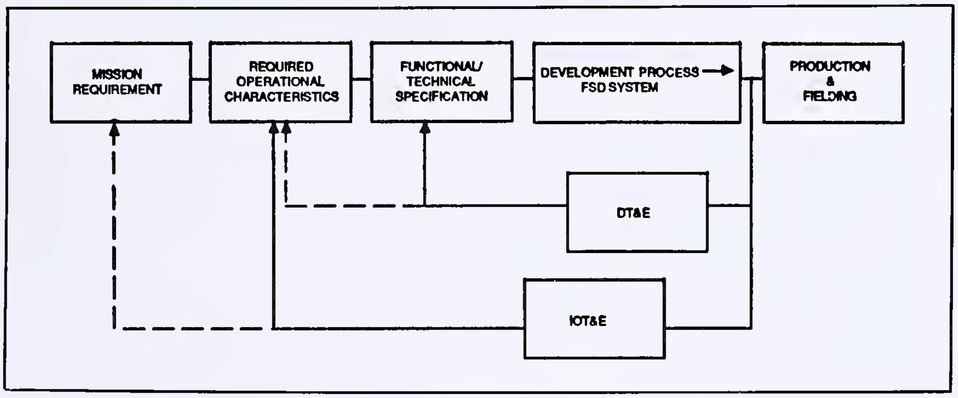
As defined by the governing directive (DODD 5000.3, "Test and Evaluation"), DT&E is conducted throughout various phases of the acquisition process to ensure the acquisition and fielding of an effective and supportable system by assisting in the engineering design and development and verifying attainment of technical performance specifications, objectives and supportability.

OT&E is the field test, under realistic conditions and by typical users, of the weapon system (or element thereof) to determine its suitability and effectiveness.

While DT&E emphasizes engineering design and technical performance, its ultimate goal, like that of OT&E, is to ensure the acquisition and fielding of weapon systems that are effective and supportable under combat conditions.

One should not expect DT&E, by itself, to be sufficient to fully ensure effective, supportable combat operation; key elements of realistic testing are reserved to OT&E, e.g., operation by typical military users in as a realistic representative field condition as possible against threat representative hostile forces. Nonetheless, it is clear that the utility of DT&E as an acquisition tool is increased when Development Test (DT) results can serve as a reliable predictor of Operational Test (OT) performance.

The accompanying diagram presents a simplified model of the weapon system acquisition process to assist in examining the relationship between DT&E and OT&E. The model suggests that test and evaluation is a continuum of activities interwoven with the acquisition process.



Model of the Weapon System Acquisition Process

In reality, the maturing DT&E and initial phases of OT&E (IOT&E) events do not fit into rigid nor discrete compartments; both are involved with broad, system-level concerns. This relationship is a matter of on-going interest and often the cause of confusion and misunderstanding. In addition, recent enactments by the Congress have drawn attention to the Office, Secretary of Defense (OSD) T&E communities' management, execution, and actions. The result of all of this certainly needs to be well understood by those engaged in the acquisition of weapon systems. Accordingly, the reader is invited to take the following true or false test and be his/her own evaluator:

The intent of this test is not to provide pass/fail criteria for the reader, but rather to clarify the on-going relationships between the DT&E and OT&E communities. More precisely, the entire test and evaluation community is currently being challenged to support the evolving acquisition goals and objectives. The use of viable test programs and the commitment to objective assessments are the essential means to achieve the results recently expressed by Army Chief of Staff GEN Carl E. Vuono — "Test and Evaluation is very important because putting less than adequate weaponry into the hands of our soldiers is a price that we all cannot afford."

The OSD test and evaluation environment is divided and fragmented.

False. That is, while the OSD T&E function is fragmented organizationally, its purpose is not. Clearly the director, operational test and evaluation (D,OT&E), is responsible for providing OT policy, while the deputy director, defense research and engineering (test and evaluation) (DDDRE(T&E)) is responsible for DT policy generation. However, both entities agree that:

- "test planning" must begin early;
- early test results are essential to support design to production decisions;
- DT objectives must posture a system for OT; and

• OT must be viewed as a graduation type of an event rather than as a final exam.

A single OSD organization would not alter this ideology at all. Two organizations permit focused attention upon a myriad of related matters such as test facilities (instrumentation and ranges), test targets, threat surrogates and simulators, live fire testing, joint tests, and foreign weapon evaluation. Most importantly, it allows independent, objective weapon system assessments from a development perspective to ensure that engineering thresholds have been attained and from an operational perspective to verify the suitability and effectiveness is confirmed prior to proceeding beyond low rate initial production.

Test and evaluation assessments go unheeded.

False. T&E assessments are an integral influence in the defense acquisition decision making process. Routine vehicles such as weekly "quick look" T&E correspondence and more detailed status reports and memoranda are frequently generated to ensure the secretary of defense and under secretary of defense (acquisition) are appraised of acquisition T&E matters. Lastly, the T&E assessments provided to the Defense Acquisition Board often form the foundation of the resultant Acquisition Decision Memorandum that directs the service acquisition executive during the forthcoming months of program execution.

Weapon system acquisition time has increased due to the demands/requirements for more testing.

False. During this past year, as a result of Congressional interest, a thorough and comprehensive review of the weapon system acquisition process judged that a vigorous, well planned T&E effort is time efficient and a wise investment. The conclusion from the evaluation of testing time is that T&E is not a reasonable target for time reduction in pursuit of a speedier acquisition process, and that a cutback in T&E could actually lead to a longer and costlier acquisition process.

Existing T&E policies of DOD and military departments are inconsistent in philosophy and approach.

False. DOD Directive 5000.3, "Test and Evaluation," sets forth the broad philosophical basis for T&E and identifies specific responsibilities and methods for all T&E actions in DOD. It highlights the purpose of testing, the relationship between DT & OT as currently defined, specific Service responsibilities, and T&E planning and execution requirements.

The Services in turn have each prepared regulations that implement the guidance contained in DODD 5000.3 for their respective organizations. In general, the Services are in concert with the fundamentals of the DOD T&E guidance, although there are differences in terminology and approach. For the most part, this is a consequence of the different weapon system classes and operating environments with which each Service must deal.

Development Test (DT) and Initial Operational Test (IOT) are incompatible in purpose.

False. T&E is an integral part of the acquisition process, interacting with other program functions that support the development of a product design and helping to determine the operational effectiveness and suitability of a weapon system. Testing (both development and operational) must begin early and be done continuously rather than viewing it as a "final exam." Accordingly, the relationship between DT and IOT is separate, yet complementary. For example, an early operational assessment is often based upon the DT data. In the end they contribute to a healthy T&E environment that is in turn helping the DOD in its decision process. DT contributes to the design portion of the process, whereas OT establishes the information base for recommending when a program is ready to proceed past a low rate initial production.

Test and Evaluation Master Plans (TEMPs) are needed solely to comply with DOD Directive 5000.3, "Test and Evaluation," i.e. to fulfill a process requirement.

False. The purpose of a TEMP is to: identify the scope of planned testing; delineate acceptable evaluation criteria; and foster sound program management by which to execute a rational, logical course of action.

The concept of a TEMP is detailed in DOD Manual 5000.3-M-1, "Test and Evaluation Master Plan Guidelines," and supports the premise that the document should be viewed as a tool to ensure program management success. The TEMP should serve as a roadmap rather than as a detailed test plan. Accordingly, program officials should use it as a vehicle to confirm, via test results, the progress of a maturing set of events. This progress is examined continuously during the development period and is necessary in order to facilitate the certification that the developing system under test is ready for OT.

Utilizing evolutionary thresholds that span the phases of advanced and engineering development right through the certification for OT readiness and leading to initial operational capability can become bona fide check points to support acquisition management decisions.

Hence, the TEMP is and should be viewed as a living document, accommodating annual updates and revisions. Meanwhile, the TEMP must track with the approved requirements and Decision Coordination/System Papers to ensure that the objective system, once fully fielded, satisfies the military user's required operational needs (the final set of evolutionary thresholds).

Accordingly, Service submitted TEMPs receive a thorough and comprehensive OSD-wide review to ensure that programmatic and technical viewpoints, concerns, and details are adequately addressed.

Until recently, software T&E has placed its emphasis more on "T" than "E" and has thus endorsed the-Design-Test-Redesign-Retest philosophy of development.

True. But the design-test-redesign approach has been observed to be both costly (see note below) and inefficient for hardware and software development efforts. Therefore, the soon to be published DOD Manual 5000.3-M-3 "Software Test and Evaluation Manual" will advocate the following:

• DOD-STD-2167, "Defense Systems Software Development," which established a tri-service approach for designing and building in software quality vice testing in software quality. Quality being one measure of software maturity;

• Development of mathematical means of determining software correctness analytically during design and prior to code development, leading the way to error reduced software being developed in a "clean-room" environment. This is still in its infancy;

• Support the DOD implementation of Ada for use in all weapon systems. This approach fosters the early detection and prevention of requirement and design errors prior to software coding; and

• Improving management visibility, testing, and assessment tools which promote management attention, early

detection, and correction of software problem areas.

NOTE: Evidence produced by software studies indicates that, on the average, approximately 40 to 60 percent of the DOD software development dollars are spent on software test related activities.

Live fire testing is solely an Army test program brought about by the Bradley Live Fire Test (LFT) effort.

False. The vulnerability of the Bradley Fighting Vehicle was initially quantified by the OSD sponsored joint live fire test effort. In FY 87, Congress established a DOD-wide live fire test mandate to be overseen by OSD and executed by each Service. The enabling legislation states that live fire testing shall be executed sufficiently early in the development phase of the system or program to allow any design deficiency demonstrated by the vulnerability testing to be corrected in the design of the system, munition or missile before proceeding beyond low rate initial production.

The TEMP is the umbrella document to record the scope of a system, munition or missile's live fire test. The supporting Detailed Live Fire Test and Evaluation Plan contains the subsystem and component or full up testing needed to assess system vulnerability or lethality. Such a full up test may be waived by the secretary of defense prior to entering Full-Scale Development and provided that the secretary certifies to Congress that live fire testing would be unreasonably expensive and impractical.

Nondevelopmental item (NDI) is an acquisition strategy that eliminates the requirement for test and evaluation master planning.

False. The use of NDI is based upon the results of a market surveillance and analysis performed early in the system life cycle. Typically, the analysis determines the feasibility of satisfying a military deficiency or need by utilizing commercial off-the-shelf products. These products may be used either directly, or ruggedized for military environments, or integrated into existing or evolving system design(s). In any case, the degree of testing will be commensurate with the degree of integration and/or modification required. It will be inversely proportional to the depth of contractor data appropriate for evaluating military operational suitability and effectiveness.

As described in the forthcoming DOD 5000.3-M-5, "Procedures Manual-Improving Test and Evaluation Effectiveness in Support of the Major Weapon Systems Decision Process," the testing of an NDI must not impede the objectives of streamlining the acquisition process. Rather, it must be accomplished in an orderly, objective fashion consistent with the approved TEMP.

A balanced structured system test plan treats hardware, software and the user as equals.

True. A balanced test plan is necessary to ensure that system and mission objectives will be supported by maturing hardware and software. The test plan must address hardware (including mission critical computer resources as well as front-end sensors), software (firmware as well as resident and data flow induced), user elements and the integration of all of these elements. System level testing should be designed and conducted to demonstrate the contribution of hardware, software and people to the quantification of reliability, availability, and maintainability parameters.

Pre-planned product improvements (P3I) or evolutionary acquisition (EA) strategies (yes there is a difference) minimize the conflict between DT and OT.

True. P3I and EA both contain a modular building block concept to enable the integration of progressive hardware and software design enhancements capable of meeting futuristic mission objectives by the phasing-in of upgradable intrinsic elements.

The enhancements result in cost avoidance in such areas as obsolete system software, planned delivery of new technology and the tailoring of operational characteristics to increase the utility of available, employable technology.

Hence, at the system level, the adoption of P3I or EA tends to minimize DT and OT conflicts by accommodating design changes over a spectrum of time as evidenced by specific development objectives and OT expectations. With a balanced test program consisting of integration, interoperability, and compatibility testing, the modular concept can provide the roadmap to reduce test and acquisition conflicts.

Concurrent acquisition strategies typically reduce schedule risk at the expense of informed decisions.

False. In the usual context, concurrency means either the simultaneous DT/OT or the more common interpretation of simultaneous DT/OT and production.

With concurrent DT/OT, the program office and contractor are faced with the dilemma of trying to collect developmental data as quickly as possible while providing and supporting a system for the independent operational tester to verify user requirements. What often happens is the curtailment or retarding of developmental data taking to ensure compliance with a particular operational performance threshold thus impeding overall development and progress toward certification for dedicated system level OT. Some concurrency in DT/OT is beneficial but only to the extent that quick look OT evaluations are used to assist the developer and help refine system specifications.

Detrimental concurrency of DT/OT occurs, for example, when the program office/contractor team candidly admits that their attention has been diverted from developmental to operational testing. Typically, this means that the preference to collect data (i.e. to fire several telemetry equipped missiles) followed by the opportunity to correct engineering deficiencies has been set aside in deference to the necessity to rehearse IOT&E to minimize the possibility of any embarrassing operational occurrences. Thus, the attainment and confirmation of development objectives, as verified through flight test, become mitigated.

Operational suitability and operational effectiveness are graduation characteristics validated as a consequence of OT.

True. The latter phase of OT (i.e., OTII), is the place to prove operational effectiveness. Whereas some of operational suitability can be assessed from the results of DT, DOD 5000.3 states that operational suitability under realistic conditions is to be validated during operational testing.

Nuclear hardness and survivability (NH&S) objectives are to be achieved in DT and confirmed in OT.

True. DODI 4245.4 "Acquisition of Nuclear-Survivable Systems," states that "NS&H objectives are (to be) achieved during DT and OT&E."

In addition, DODD 5000.3, "Test and Evaluation," states that "DOT&E is responsible for (confirming), in coordination with the assistant to the secretary of defense for atomic energy, ATSD(AE), that OT&E confirms NH&S as intended." "DDRE (T&E) is responsible for confirming, with advice from the

ATSD (AE), that NH&S objectives are achieved during DT&E."

As we all are aware, testing to confirm nuclear hardness and survivability must depend upon a combination of tests, simulations and analysis. And like the non-nuclear survivability area, the severity of the mission degradation will be extrapolated in terms of the ability of the threat operating environment to exceed the system design capabilities thereby affecting system survivability.

The degree to which the system survives will directly contribute to mission abort, mission degradation, nuisance or no response. In the end, the system's design (development objective) must be robust to lie somewhere between impervious to the expected threat (i.e., no vulnerability), to built-in recovery (observable degradation) and the acceptance of partial (but militarily acceptable) operational suitability and effectiveness.

WES Expands Educational Programs

Editor's Note: The following is a summary of an article titled "Importing Education — An Army Lab's Pursuit of Excellence" that was published in the October 1987 issue of the Government Executive.

Mississippi State University has been offering master's degrees in civil engineering and engineering mechanics at the Vicksburg Center for Graduate Study in Engineering on location at the Waterways Experiment Station (WES) since 1965.

Nearly 65 WES employees earned master's degree from Mississippi State at the Vicksburg Center through 1985. During this same 20-year period, the number of engineers and scientists at WES increased 133 percent. The different disciplines represented among the professional staff also increased from 12 in the early 1960s to 40 in 1985. Twelve of the new disciplines are in the biological sciences which were not represented at all during the early 1960s.

It was clearly evident that there was a need to offer more educational programs at WES to meet the demands of the expanding work force. Now, because of an innovative program initiated by WES management, the 1,050 engineers and scientists working in Vicksburg — 700 at WES and 350 more at two other Corps of Engineers field offices — have ready access to educational programs from three regionally prominent universities through the WES Graduate Institute.

The WES Graduate Institute is an association of the three universities and WES through which academic credit and graduate degrees can be earned from member universities by course work offered at WES. The institute was established in 1986 to support graduate study and research in scientific and technological areas of interest to WES and other Corps elements.

The institute was formed primarily with the educational needs of WES employees in mind, but its benefits extend beyond the individual. For example, the institute enhances the exchange of scientific and technological information between member universities and WES, provides a mechanism through which researchers maintain technical competence and continue professional development, and facilitates recruitment and retention of quality employees.

The institute functions through joint agreements between WES and member universities. Member universities are Louisiana State, Mississippi State (including the Vicksburg Center for Graduate Study in Engineering), and Texas A&M. Programs in marine sciences and marine geology are offered by Louisiana State; oceanography, ocean engineering, and engineering geology are from Texas A&M; and instruction in civil engineering and engineering mechanics are from Mississippi State.

Mississippi State was recently requested to expand its engineering curriculum at WES and to offer programs in computer science, math and statistics, and the biological/wildlife sciences. The State College Board is expected to approve the program expansion in the near future.

Member universities apply the same academic requirements and standards to their institute courses as they do to courses offered on their main campuses. Students may enroll as degree or non-degree students and receive academic credit for courses completed. Those in degree programs must meet all the requirements of the university in which they are enrolled, including admission to the program, forming an advisory committee, and having their program of study approved.

Most courses taught at the institute are taught by faculty from member universities who either commute there once a week or move to Vicksburg temporarily. While at WES, university faculty teach at least one course per semester and participate in on-going research or conduct independent research that relates to a WES program.

Some courses are taught by WES employees that have been elected to serve as adjunct or affiliate faculty of a member university. Employees who take classes are expected to continue performing a full load of job responsibilities. For this reason, classes are not scheduled before 4 p.m., and WES employees, whether participating as students or faculty, apply flextime to attend classes.

During the 1986-87 academic year, there were 194 students enrolled in courses. One-hundred-fifty-five of the students were WES employees and this represents over 20 percent of the engineers and scientists employed at WES.

The institute greatly increases the graduate educational opportunities at WES, but is limited by the logistics of scheduling faculty and courses and obtaining a necessary minimum level of student demand. The possibility of satellite transmission of courses between the universities and WES is being discussed as a way to eliminate geographic obstacles, reduce planning constraints, and increase the access to a greater number of courses and faculty.

Providing access to graduate education sends a clear message to WES employees that the organization cares about their professional and personal development. Although the method may be gradual and indirect, WES management believes that enhancement of employee capabilities will not only boost morale but is also the surest way to institutionalize organizational excellence and prestige.

The Army Science Board. . .
An Independent Assessment of Army Programs

By COL Richard E. Entlich

Introduction

What is the Army Science Board (ASB)? How does it function? How can I get the board to help solve some of my problems? These questions, along with many others, are frequently asked of the Office of the Assistant Secretary of the Army for Research, Development and Acquisition.

The Army Science Board is the senior scientific advisory group to the secretary of the Army and is comprised of approximately 100 distinguished members from the industrial, academic, and research communities. The basic missions and policies of the ASB are:

- to provide technical review and management support to major Army programs in critical need of DA attention;
- use specialists to provide quick reaction in response to technical review and assessment of major program initiatives;
- use members as ambassadors to keep the Army alert to new science and technology developments in industry that will meet new operational requirements or increase operational readiness; and
- use members as consultants to the Department of the Army in science and technology activities.

History

The illustrious history of the Army Science Board began in 1951 when it was originally established by the secretary of the Army, the honorable Frank Pace, on a trial basis as the Army Scientific Advisory Panel. In 1954, the 10-member panel became a permanent Department of the Army board and its membership was expanded to 25.

ASB member trying on jumper's equipment at Fort Bragg

Activities of the panel accelerated substantially in 1956 with the formation of subpanels which investigated broad areas of interest to include air mobility, communications and electronics, firepower, and environmental research. However, after a panel reorganization in 1963, the subpanel structure was abolished in favor of an ad hoc group system.

The Army Science Board, as it exists today, was chartered in December 1977 to perform the duties previously accomplished by the Army Scientific Advisory Panel and several other U.S. Army scientific advisory panels and committees.

ASB members enjoying lunch in the field with soldiers from Fort Bragg.

Organization

The Army Science Board functions under the direction of the assistant secretary of the Army for research, development and acquisition. The assistant secretary appoints a senior Army official to the position of executive secretary of the board.

The executive secretary is an ex-officio member of the board and acts as a liaison between the assistant secretary and the board. Completing that link are the chairperson and vice chairperson who are selected from the membership by the assistant secretary and approved by the secretary of the Army.

The current chair of the Army Science Board is Gilbert F. Decker, president of Penn Central Federal Systems Co. The vice chair is Dr. John W. Knapp, dean of the faculty at Virginia Military Institute. The chair and vice chair normally serve for a term of one year.

As part of the organization of the general membership, the members of the Army Science Board are assigned to five standing groups known as functional subgroups according to practical experience and interest. These functional subgroups include: weapons systems; command, control, communications and intelligence; human capabilities and resources; logistics and support systems; and research and new initiatives. Each subgroup is tasked with maintaining cognizance of the Army activities and needs within its functional area.

Shown conversing during the ASB semiannual general membership meeting at Fort Bragg are (left to right) Assistant Secretary of the Army (RD&A) Dr. J. R. Sculley, ASB Chairman Gilbert F. Decker, and Secretary of the Army John O. Marsh Jr.

Membership

Members of the Army Science Board are selected according to their preeminence in the fields of science, technology, engineering, testing, acquisition, and management. They are affiliated with organizations such as the National Academy of Science, National Research Council, and the National Academy of Engineering.

Nominations for members are received from both the government and private sector. Members are appointed for 2-year terms and may serve up to three consecutive terms. Upon final appointment, board members are eligible to work up to 60 days during each appointment year. Membership of the Army Science Board is limited to no more than 100.

Meetings

Board members serving on ad hoc subgroups meet periodically during the year at the call of the ad hoc subgroup chair. In addition to meeting with their respective subgroups, ASB members gather twice a year, once in the spring and once in the fall, for general membership meetings.

Held at various Army installations,

the general membership meetings provide a forum designed to further educate members in the workings of the U.S. Army. The meetings are also used to update the members on the year's events.

Reports

The Army Science Board publishes anywhere from five to 10 reports per fiscal year. Topics for study are solicited from the senior Army leadership by the assistant secretary who ultimately decides upon and approves the topics.

Once a study topic has been accepted, the executive secretary, chair, and vice chair appoint appropriate board members as an ad hoc subgroup for the purpose of researching the issue. The sponsor of the study provides terms of reference to guide the members in their research.

Upon the completion of research, the subgroup publishes a report of its findings and recommendations. Recent major studies completed by the board include "Lightening the Force," "Environment, Real and Induced — A Force Cost Driver," "Information Management Concepts and Architecture," and "Army Biological Defense Research Program." Top priority is given to the implementation of Army Science Board recommendations.

A senior Army official, working in direct coordination with an ASB point-of-contact, is assigned to oversee the Army's implementation of these recommendations. In addition to these ad hoc subgroups, effectiveness reviews of Army research and development organizations are also conducted. To date, 13 of the Army's laboratories and research, development and engineering centers have undergone this process, to include the Atmospheric Sciences Laboratory, the Armament Research, Development and Engineering Center, and the Engineer Topographic Laboratory.

Summary

The Army Science Board continues to provide the Army's leadership with timely reports regarding some of the hard to tackle scientific and technical matters that we face in the future. These findings and recommendations often provide the basis for major decisions in the research, development and acquisition area.

Additional information concerning the Army Science Board can be obtained by writing: Army Science Board, Office, Assistant Secretary of the Army (RDA), ATTN: SARD-ASB, Washington, DC 20310-0103.

COL RICHARD E. ENTLICH is executive secretary of the Army Science Board, Office of the Assistant Secretary of the Army for Research, Development and Acquisition. He graduated from the U.S. Military Academy in 1963 with a B.S. degree in military engineering and has an M.S. degree in applied mathematics from the University of Missouri.

CERL Joins in Cooperative R&D Agreement

The first cooperative research and development agreement (CRDA) between an Illinois firm and the U.S. Army Construction Engineering Research Laboratory (CERL) was signed late last year. Electronic Courseware Systems Inc. (ECS) of Champaign, IL and CERL entered into the agreement for the further development of CERL's Teaching Assistant Program. CERL Commander COL Norman Hintz and ECS President David Peters signed the agreement at CERL.

CERL developed Teaching Assistant for training architects and engineers to use the automated drafting and design programs. The Teaching Assistant was developed to teach drafting concepts in a commercially available drafting program called AutoCAD. The users are monitored and feedback is provided in case of expected errors or failure to try the examples. It allows users to proceed at their own pace according to individualized learning styles.

The process of completing the lessons constitutes actual practice with the AutoCAD system. Such lessons are designed to provide an alternative to the traditional forms of instruction on procedural forms of on-line training. The lessons have been tested at various government and university test sites.

The CRDA is made possible under the Federal Technology Transfer Act of 1986. This act directs federal departments and agencies to improve the transfer of federally developed technology and technical information to the marketplace. Commenting on the act, ECS President Peters said, "This legislation encourages publishing companies to develop research technology as products, making them available to the private sector." The act allows federal laboratories to collaborate with state and local governments, universities and business, particularly small business, through cooperative research and development agreements.

The CRDA is unique to the federal government because it was developed with computer software in mind rather than patentable products. The CRDA will be used as a model for future software CRDA's within the Corps of Engineers labs.

CERL advertised its requirements in the *Commerce Business Daily*. ECS Inc. was one of a number of firms responding. "ECS Inc. has the educational background we were looking for," noted CERL Commander Hintz, "and, since they are a local firm, I'm confident this agreement will result in a mutually beneficial relationship."

According to Peters, "The quality of software developed by CERL is excellent." He continued, "the systematic development and evaluation process used by the CERL staff through user testing has yielded a highly effective instruction package for professional engineers and architects. ECS looks forward to the opportunity of publishing these high quality materials." It specializes in the design and development of computer-based learning materials.

CERL is a U.S. Army Corps of Engineers research laboratory located in Interstate Research Park on the northwest side of Champaign, IL. The lab conducts research in support of the construction, operations, and maintenance of more than 150 Army facilities worldwide.

Computerized Monitoring of Subsistence Quality

By CPT Anthony H. Kral and Dr. Robert R. Zall

Introduction

The American soldier is probably the best fed soldier in the world. From "high-tech" field rations like the meal, ready-to-eat and the tray pack, to nutritious foods in the garrison dining facility, enormous effort and resources have been expended to ensure the best and highest quality food possible for our soldiers.

While most quality control effort has been focused at the point of product origin or manufacture, there is a need to extend our oversight of product quality into the storage and distribution system. Quality loss in food products, caused by temperature abuse during storage and distribution, has been well documented. For this reason, it is important to know when subsistence stocks have been thermally abused and what effect such abuse has had on product quality.

During storage and distribution of food, the military services mostly rely on veterinary inspection and date-of-pack (DOP) stock rotations to monitor conditions that keep food products consistent with high quality standards. Unfortunately, this system of "quality assurance" is costly in terms of manpower and may not consistently deliver a high quality food product to the soldier. This situation exists because the DOP stock rotation policy assumes that all product lots, in a given stockpile, have deteriorated at a uniform rate. However, food products usually encounter a variety of temperatures during distribution.

Since quality deterioration can be directly related to temperature, product lots may actually be at varying levels of deterioration based on each lot's thermal exposure. The DOP stock rotation policy does not recognize storage differences and is unable to compensate for these variations in product quality.

To account for this non-uniform deterioration, a device or mechanism which monitors product quality, based on time and temperature exposure is useful and needed. Ideally, this mechanism should allow product quality to be used as a criteria for stock rotation and should require the same or better still, fewer resources than the current system of inspection.

A new system that claims to perform many of the above mentioned functions is the LifeLines Inventory Management System, developed by LifeLines Technology Inc. of Morris Plains, NJ. A study conducted at Cornell University, in cooperation with military, educational and commercial organizations, examined this system and evaluated its performance using subsistence stocks in military distribution. While this was a separate study, it was intended to complement work being done by the U.S. Army Natick RDE Center on this and other time-temperature indicating systems.

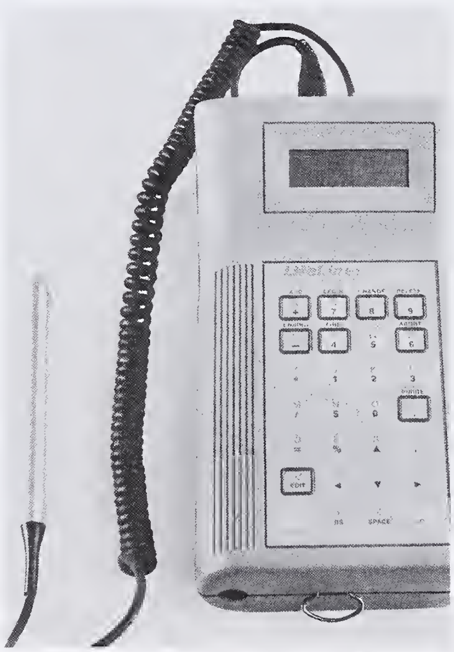


Figure 1. Hand-Held Microcomputer.

System Description

The LifeLines system consists of three major components; an indicator label, a portable, hand-held microcomputer and an IBM PC/XT or compatible personal computer.

The indicator label consists of two distinct types of bar codes. These codes provide product specific information and identify the type of indicator used on the label. The other code contains the time-temperature indicator; a polymer strip which irreversibly darkens with accumulated time and temperature exposure. Several polymers have been developed for use with a variety of products.

The portable, hand-held microcomputer with scanning wand, Figure 1, reads the bar codes and measures the amount of light reflected from the polymer strip. As the strip darkens, the reflectance reading decreases. Using product quality information from laboratory shelf life tests, the microcomputer can be programmed to project shelf life loss to date and estimates the remaining shelf life of the labelled food product. Previous studies at Cornell University have demonstrated the capability of the system to predict the remaining shelf life of both semiperishable and perishable foods.

Information from the hand-held microcomputer can be transferred from distant warehouses to a central location using the remote communications capability of the system. An IBM PC/XT computer or compatible unit receives the information and processes the data using special inventory management software. The software can provide thermal history reports of the product, as well as pick lists and shipping sequences based on product quality.

Figure 2 illustrates how the system's components work together in an actual distribution environment. In short, "LifeLines" is a systematic application of some new technology which makes it possible to rotate subsistence stocks based on quality or remaining shelf life rather than date of pack. Using a quality based-issue policy instead of DOP, more recently processed food products, which had undergone stress during transit, could be released for use ahead of older stocks, already in inventory, which have a longer remaining shelf life.

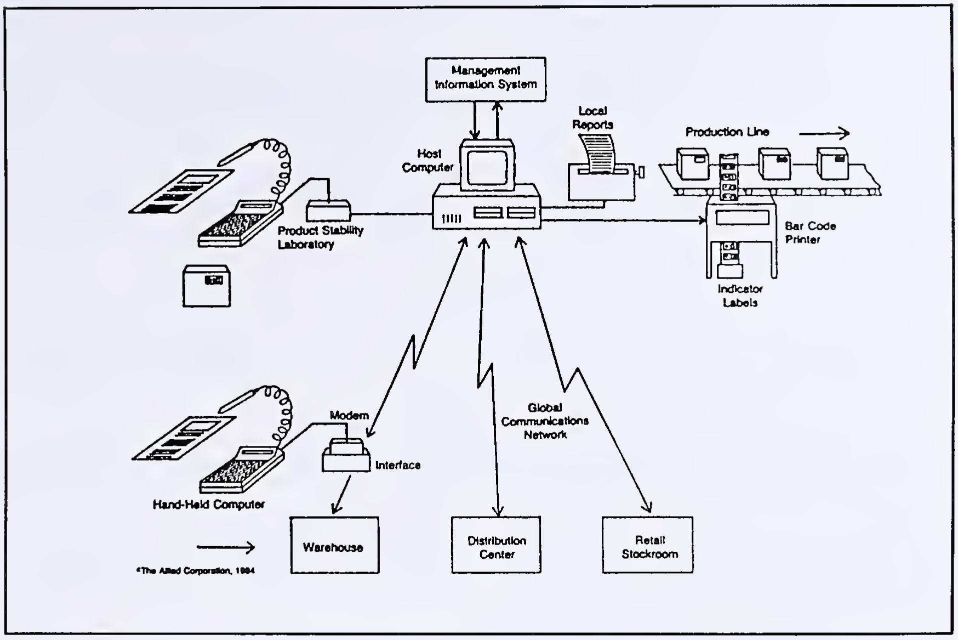


Figure 2. Integrating the Components of the Lifelines Inventory Management System.

Challenging The System

Our study challenged the new polymer indicating system with (A) frozen orange juice concentrate and (B) fresh fruits and vegetable produce which were procured from commercial suppliers for distribution to military dining facilities and commissaries.

In case A, indicator labels were applied to 1,200 cases of orange juice concentrate immediately after the juice was processed. Using the hand-held microcomputer, indicator labels were read at the processing plant and later at key points in the storage and distribution system. Indicator label data were transmitted, in the field, using an acoustic coupler modem from both the processing plant and storage facility to an IBM PC/XT computer maintained at Cornell University.

In case B, indicator labels were placed on several hundred cases of fresh produce. The produce was obtained by government purchasing agents at the Hunts Point Terminal Market in Bronx, NY. Labels were applied and read at the terminal market and later as the produce moved through the distribution network. Indicator information was transmitted to Cornell University using an automated, electronic modem.

Component Performance

The orange juice and produce examinations allowed the authors to observe how well the LifeLines system components performed in the military's distribution environment. We found that indicator labels adhered well to both corrugated paperboard and wooden shipping containers. The labels proved to be extremely durable, with only 19 of the 1,200 orange juice indicators being damaged in distribution and all damage occurring in areas where the shipping container itself had been abused.

The hand-held microcomputer with its optical scanning wand performed well under a variety of environment conditions; such as in a blast freezer, storage freezer, refrigerated cooler and loading docks. In most areas, a scanning success rate of 90 percent was achieved. That is, nine out of 10 passes of the scanning wand resulted in a successful indicator reading. However, ice build-up and extreme cold (-20 F) interfered with scanning operations in the blast freezer.

Remote communications were successfully transmitted using both an older-type acoustic coupler modem and with a newer, more automated, electronic modem. A drawback to the acoustic coupler was its susceptibility to disruption by background noises and its slow transmission speed (300 baud). The electronic modem, on the other hand, is four times faster (1,200 baud) and is not as sensitive to background disturbances. However, a newer modem does require access to a telephone line equipped with an RJ11 modular plug.

Two special considerations in using the system warrant mentioning. First, the hand-held microcomputer is unable to read indicator labels through shrink wrap used to contain pallet loads. Second, because indicators are active when manufactured, indicator labels, particularly those for frozen foods, need to be maintained at low temperatures prior to use or application.

Data Analysis

Data from the indicator labels allowed us to track the average temperature and remaining shelf life of the food products. Table 1 provides a summary of data from the orange juice evaluation.

Referring to Table 1, the percent of reflectance value is the average indicator reading and represents the amount of light reflected from the polymer strip. Based on the percent of reflectance reading and the elapsed time, cumulative and intermediate kinetic average temperatures (KAT) were calculated. The cumulative KAT is the average temperature that the concentrate has been exposed to since the initial indicator reading on day zero.

The intermediate KAT represents the average temperature exposure of the juice from point to point in the distribution network. By way of example, the cumulative KAT on day 39 of the test is 8.6 F. This was the average temperature that the concentrate had been exposed to since it was processed. On the other

hand, the intermediate KAT for day 39 was a slightly lower 6.8 F, which was the average temperature exposure of the juice since day eight of the test.

The hand-held computer was able to provide a direct readout of product quality in the form of "remaining shelf life." Our hand-held unit was programmed to monitor orange juice concentrate with a shelf life of 52 weeks when stored at 0 F. Higher temperatures accelerate product deterioration and reduce the remaining shelf life. For example, the remaining shelf life of the orange juice at day 39, with an average temperature exposure of 8.6 F, was 39 weeks. Had the concentrate been stored at 0 F, the remaining shelf life would have been 46 weeks. In effect, seven weeks of shelf life was lost due to thermal abuse.

All indicator readings, except for day eight, decreased in value during the course of the study. The slight increase in reflectance readings, between days seven and eight, was probably due to ice build-up on the tip of the scanning wand. This ice build-up was noticed while reading labels in the manufacturer's blast freezer, on day seven, and could have hindered the scanning wand's ability to detect the indicator strip's full reflectance.

The produce examination allowed us to develop a temperature profile of fresh fruit and vegetable distribution (Table 2). Based on the cumulative and intermediate KATs, we can see that the produce was exposed to the highest storage temperatures while at the Hunts Point Terminal Market and while enroute to the storage facility. The lowest temperature exposures were found at the commissary.

TABLE 1. ORANGE JUICE TEST DATA

DAYS	% REFLECTANCE	KAT °F[1] CUMULATIVE	KAT °F[1] INTERMEDIATE	REMAINING SHELF LIFE (WKS)
0	91.00	--	--	52
7	86.07	16.2	16.2	47
8	87.78	11.8	*	49
39	76.66	8.6	6.8	39

1 KAT: KINETIC AVERAGE TEMPERATURE. REPRESENTS THE AVERAGE TEMPERATURE A PRODUCT HAS BEEN EXPOSED TO DURING STORAGE AND DISTRIBUTION.

* TEMPERATURE COULD NOT BE CALCULATED.

DISTRIBUTION SCHEME

DAY 0-7: ORANGE JUICE STORED AT PROCESSING PLANT
DAY 7-8: ORANGE JUICE IN-TRANSIT TO STORAGE FACILITY
DAYS 8-39: ORANGE JUICE MAINTAINED IN STORAGE FACILITY

Conclusions

While this study was limited in scope, it demonstrates that a computerized, polymer-base, time-temperature indicating system, similar to LifeLines, could possibly be used to monitor subsistence stocks in military distribution. The remote communications capability facilitates the management of widely disbursed stocks from a central location. Indicator information can provide distribution managers with enhanced visibility over temperature control in the distribution network. The quality projection capability could allow the rotation of stocks based on remaining shelf life rather than date of pack, with the potential of providing food products of higher and more consistent quality to our soldiers.

Although this study used food products, one could speculate that this technology might also be used for munitions, chemicals, medical supplies and other temperature sensitive materiel.

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DR. ROBERT R. ZALL is a full professor in the Department of Food Science at Cornell University. He holds a B.S. and an M.S. from the University of Massachusetts and a Ph.D. from Cornell University.

TABLE 2. FRESH FRUITS AND VEGETABLE PRODUCE TEST DATA

HOURS	% REFLECTANCE	KAT °F CUMULATIVE	KAT °F INTERMEDIATE
0	88.95	--	--
12	76.04	65.7	65.7
25	66.04	63.9	62.1
108	50.88	51.3	43.5

DISTRIBUTION SCHEME

HOUR 0-12: PRODUCE AT HUNTS POINT AND ENROUTE TO STORAGE FACILITY
HOUR 12-25: PRODUCE AT STORAGE FACILITY AND ENROUTE TO COMMISSARY
HOUR 25-108: PRODUCE STORED AT COMMISSARY

High Temperature Superconductors

By MAJ Robert J. Bonometti
and 1LT Richard Benfer

Introduction

On July 28, 1987, President Ronald Reagan delivered the keynote address at the Federal Conference on the Commercial Applications of Superconductivity. Speaking before an assemblage of national leaders in science, engineering, and corporate and entrepreneurial technology management, the president heralded "the breakthroughs in superconductivity [which] bring us to the threshold of a new age." The president called upon his audience to lead the United States to victory in the global war currently underway to achieve dominance in the emerging multi-billion dollar industry of high temperature superconductor technologies.

To support this effort, Reagan launched a "Superconductivity Initiative" aimed at providing financial support and establishing the best environment for American business to achieve success in the worldwide competitive race to develop the technologies for superconductor applications. A significant component of this initiative entails support for Department of Defense sponsored research into potential military applications of superconductors.

What are these new wonder materials for modern science and what properties do they possess that make them so special? Why did the discovery of high temperature superconductivity win the Nobel Prize in Physics in 1987? And why has excitement about superconductors spread from the laboratory to virtually every household in the nation as the news media continuously keeps the public abreast of the latest developments with front page articles and cover stories?

In the following discussion, we will examine what superconductivity is, why the recent breakthroughs are so important and so exciting, and why this emerging technology is vitally important for future commercial and military applications. In particular, we'll take a look at what the Army is doing in this new hi-tech area.

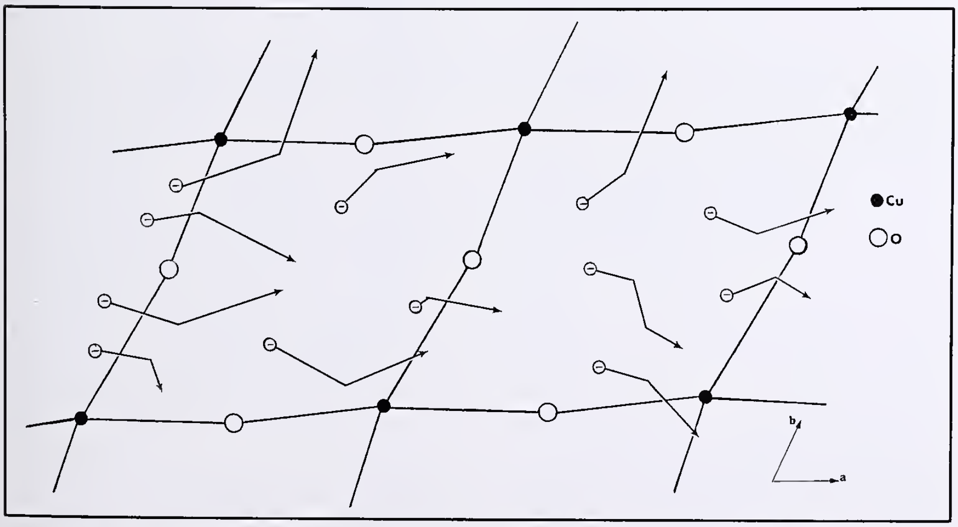

Figure 1. Scattering of electrons in a normal metal produces resistance to current flow.

What is Superconductivity?

The electrical resistance of a normal conductor (a metal) decreases as its temperature is lowered, because the thermal "jiggling" of the atoms in the metallic crystal lattice decreases. The flowing electrons which constitute the current are scattered (i.e. deflected) by other electrons and by the jiggling atoms with which they collide (see Figure 1). These atomic obstacles therefore resist the flow of current. One might expect then that electrical resistance would disappear only at absolute zero or about -459 F when all of the heat energy has been removed and the atoms no longer vibrate in the lattice.

Superconductivity is the absence of any electrical resistance at temperatures above absolute zero. It is important to emphasize that the resistance is not merely small, it is exactly zero. The discovery of superconductivity dates back to 1911, when the Dutch physicist Kamerlingh Onnes found that the electrical resistance of mercury vanished at a temperature close to, but above, absolute zero. The temperature at which a piece of material becomes superconducting is known as its transition temperature. In the years since 1911, many other materials (metals, semiconductors, and even insulators) have been discovered to exhibit the resistance-free conduction of electricity at very low

temperatures.

Although they are scientifically fascinating, applications of superconductivity have been limited by the very low temperatures which they require. From discovery in 1911 to 1986, the highest temperature at which the phenomenon had been observed was only about 23 degrees above absolute zero. In fact, theory suggested that superconductivity could not exist above about 30K. (The Kelvin temperature scale, with temperature measure in degrees K, has its zero point at absolute zero; room temperature is about 300K and liquid Nitrogen boils at a temperature of 77K.)

A fundamental theoretical understanding of superconductivity eluded physicists for many years. A successful theory was finally formulated in the early 1950s by Bardeen, Cooper, and Schrieffer, and came to be known as "BCS Theory" after its founders. To produce a viable theory, these physicists built their theory on the branch of modern physics known as quantum mechanics, whose laws govern the behavior of microscopic systems such as electrons in a lattice.

Although the mathematical details of BCS theory are quite sophisticated and complex, the basic physical ideas are fairly straightforward to understand. If all of the electrons moving through a lattice were travelling in the same direction with the same velocity, like soldiers marching in formation, then collisions would be prevented (see Figure 2). The electrical resistance in a material would then be zero.

Unfortunately, a fundamental law of nature forbids all electrons from having this "lock-step" behavior. This law requires all members of a certain class of elementary particles, known as fermions, to have different velocities if they are in the same system (i.e. in the same crystal lattice). Electrons belong to this class of particles known as fermions. Another class of elementary particles, known as bosons, are permitted to travel in "lock-step" formations.

If electrons could somehow pair-up together, then the pairs would behave as bosons and resistance-free flow could occur. The only problem is that electrons all have the same negative charge, and like charges repel. So how could electrons possibly pair together?

This problem was elucidated by a very clever mechanism. A conduction electron moving through a lattice of positive ions attracts ions as it passes nearby them. This distortion of the lattice results in a temporary concentration of positive charge, which can then attract another electron. Two electrons can thereby become coupled together via their mutual attraction to a positive charge center in the lattice. It is this coupling mechanism that produces bound pairs of electrons. These bound pairs, known as Cooper pairs, now constitute a system of bosons which can form a super current.

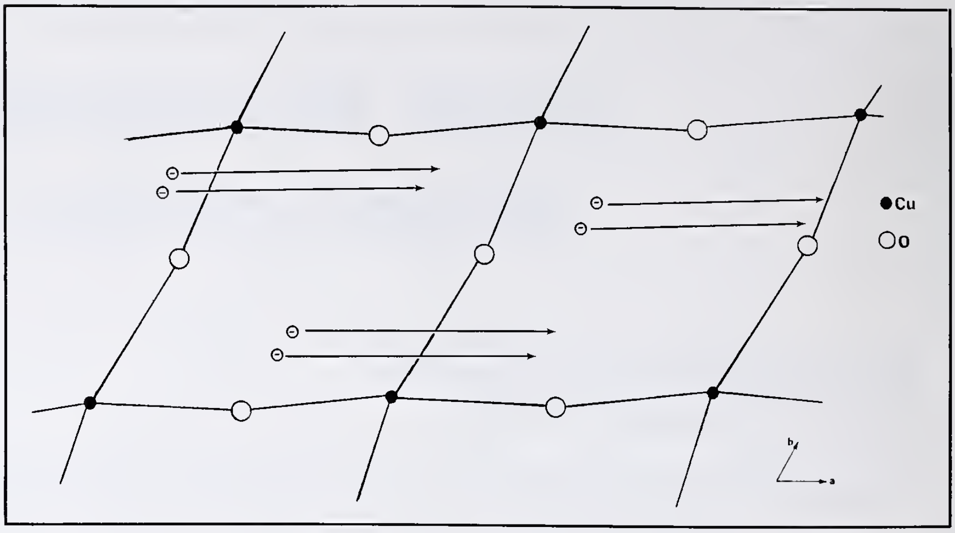

Figure 2. Simplified illustration of paired electrons moving in lock-step formation without resistance in a superconductor.

Major Properties

In addition to resistance-free conduction of electricity, superconductors display another very important property. A superconductor expels a magnetic field from its interior. Superconductors are able to behave this way because of the basic interaction between a changing magnetic field and charged particles. In the presence of a changing magnetic field, a charged particle, such as an electron, experiences a force (this fact of nature is known as Faradays's Law). When a piece of material is brought into the region where a magnetic field exists, that material "sees" a changing magnetic field environment (i.e. it sees the field increasing from zero strength up to its full intensity).

The electrons in both normal conductors (metals) and superconductors are accelerated by the changing magnetic field which they experience. However, the flowing electrons in the normal conductor are quickly decelerated to rest by collisions, their kinetic energies being converted to heat. The electrons in the superconductor, on the other hand, are not scattered and they form a persistent current which flows near the surface of the superconducting material.

A flowing electron current produces a magnetic field (this is a manifestation of Ampere's Law), as anyone who has operated an electromagnet knows. The persistent electron current in the superconductor therefore generates a magnetic field, and this field cancels the external magnetic field in the interior of the superconducting material.

This ability to shield its interior from an external magnetic field is possible only up to an upper limit called the critical field. For external magnetic fields which exceed the critical field, the superconductor is unable to expel the field, and, in fact, the superconducting state is destroyed. In other words, when placed in a sufficiently strong magnetic field, a superconductor returns to its normal state.

Since a current generates a magnetic field, and since a sufficiently strong magnetic field destroys superconductivity, one might well ask: "How large a current can a superconductor carry before it destroys its superconducting ability?" This is an important question, since one of the major properties of superconductors for technological applications is their ability to carry large currents. The maximum limiting current is known as the critical current. Exceeding a superconductor's critical current could be quite catastrophic, since the return to the normal state produces large restitive heating which can damage the material.

Figure 3. A magnet floating above a superconducting disc. Photo courtesy of J. Marzik.

Utility of Superconductor Properties

We have seen that the three basic characteristics of a superconductor are its ability to carry an electric current without resistance, its ability to exclude a magnetic field from its interior, and its ability to carry very large currents up to the critical current. Let's examine some of the general types of applications which stem from these basic properties. Later, we will discuss specific applications in greater detail.

The resistance-free conduction of electricity allows superconductors to carry electric power efficiently and economically, since loss of electric power to heat is circumvented. Thus, both the transport and use of electric power in devices (such as motors) could be performed more efficiently by superconductors than by normal conductors.

The ability of superconductors to carry currents without generating heat also has important implications for microelectronics, particularly computer systems, where many electronic components are packaged tightly together. Systems could be designed to be denser, and hence faster, if superconductors were incorporated in their architecture.

The ability of a superconductor to exclude a magnetic field from its interior also has interesting ramifications for applications. The magnetic field which the superconductor generates in the presence of an external field opposes that external field. These opposing fields push against one another, resulting in equal and opposite forces on both the superconductor material and the source of the external magnetic field. These repulsive forces can be large enough to overcome the pull of gravity, resulting in magnetic levitation. This phenomenon has been popularized in "floating magnet" demonstrations in which a small, powerful magnet is observed to float above a superconductor (see Figure 3). Perhaps the best known application of using superconductors is the proposal for a high speed magnetically levitated train, which the Japanese are interested in building.

The ability of a superconductor to carry very high currents and consequently generate very high magnetic fields leads to a host of important applications, including magnetic propulsion (again based on the repulsive force between opposing magnetic fields). An important application of magnetic propulsion, which we will address shortly, is the electromagnetic rail gun.

On the Pioneering Frontier

As we noted, superconductivity theory had predicted that the highest transition temperatures achievable (at atmospheric pressure) could not exceed about 30 K. At high pressure, it was expected that higher transition temperatures might exist, but clearly elevating the transition temperature by putting the superconductor under enormous pressure was not a desirable approach for technological applications. In any event, researchers (including a few Army scientists) had been studying superconductivity at high pressures. Dramatic progress resulted when researchers realized that the same internal effect on a crystal lattice produced by high pressure could be produced by appropriately tailoring the lattice itself. In other words, a suitably designed crystal structure might yield a high transition temperature even at normal atmospheric pressure.

These ideas were successfully implemented by IBM scientists in Zurich. The team of Bednorz and Muller discovered that the ceramic oxide La2-xBaxCuO4 (Lanthanum Barium Copper Oxide) had a transition temperature over 30 K. So important was their discovery, that superconductivity did exist above 30 K that Bednorz and Muller received the 1987 Nobel Prize in Physics for their work.

Shortly after the IBM team's exciting breakthrough, a team headed by Paul Chu of the University of Houston discovered a transition temperature more that twice as high. Chu and collaborators found that the ceramic oxide YBa2Cu3Ox had a transition temperature of 93 K. This discovery electrified the physics and material sciences communities not only because of the enormous jump in elevating transition temperature, but also because it opened an entirely new dimension for superconductor applications.

Since the YBa2Cu3Ox material had a transition temperature above the boiling point of liquid Nitrogen, the expense and complexity of liquid Helium refrigeration systems would no longer be required to reach the realm of superconductivity. Perhaps even more important than Chu's discovery itself was the optimism and excitement which it infused into the scientific community. For the first time, people were talking in a serious fashion about the potential for room temperature superconductors and the panorama of technological applications which it would make possible.

The materials which displayed these incredible properties are themselves a matter of great interest. First of all, they are ceramics, which most people probably think of in terms of dinnerware and

insulators! Secondly, their preparation required rather straightforward, simple materials processing techniques. (Indeed, given the necessary chemicals, a high temperature superconductor can be made in a ceramics hobby shop!) Figure 4 illustrates the complex crystal structure of the YBa2Cu3Ox superconductor.

Further Research

Despite the exciting and dramatic breakthroughs, much further research needs to be done to understand the physical mechanisms responsible for high temperature superconductivity. A sound theoretical understanding of the physics underlying the phenomenon will hopefully lead to development of the capability to tailor material properties and, in particular, to produce new materials with even higher transition temperatures.

Theorists are currently hard at work attempting to understand the physical basis for high temperature superconductivity. The basic framework of BCS theory is expected to remain intact; however, the mechanism which mediates the pairing of electrons can no longer be lattice vibrations. Rather, current efforts are examining exotic novel mechanisms to mediate the coupling interaction, such as excitons, plasmons, and antiferromagnetic spin fluctuations.

In addition to these efforts to understand the phenomenon, other research thrusts are focused on materials science issues. Processing techniques will enable scientists to control the crystal structure and hence to control parameters such as transition temperature and critical current limit. Developing techniques to prepare the ceramic superconductors in forms such as wires, bulk single crystal solids, and thin films, is critical to the ultimate incorporation of high temperature superconductors into useful applications.

Ceramic materials are brittle and are not easily drawn into wires, and this manufacturing capability is important for many device implementations. Another key problem area concerns present inability to grow single crystal pieces of ceramic superconductors. Preparation of single crystal thin films is important for the design and fabrication of microelectronic devices which incorporate superconductors. Dramatic developments are required in material processing technologies to be able to fabricate hybrid microelectronic devices which package both semiconductor elements and superconductor elements on the same integrated circuit chip. New concepts are needed because the high temperatures required to process the ceramic superconductor elements will destroy the semiconductor material.

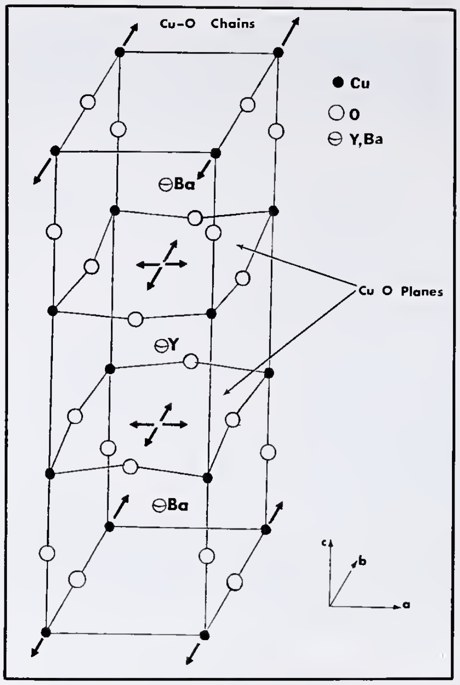

Figure 4. The crystal structure of the ceramic superconductor YBa_2-Cu_3O_x.

Material scientists must also resolve stability problems if the new ceramic superconductors are to be utilized in practical applications. Problem areas include breakdown of the material structure after prolonged exposure to the atmosphere.

We next turn our attention to current efforts aimed at producing useful applications for the new superconductors.

Commercial and Military Applications

Although they have been around for quite some time now, applications of superconductors have been limited by the extremely low temperatures previously required to reach the superconducting domain. The recent breakthroughs imply that previous superconductor applications can now be implemented in a simpler and less expensive manner using liquid nitrogen refrigeration systems. Furthermore, if (and hopefully when) room temperature superconducting materials are developed, the list of superconductor applications will multiply drastically since no refrigeration systems would be required at all.

We should note that temperatures in space are below the transition temperatures of the new ceramic superconductors. Therefore, these materials may have great impact on satellite and space-based systems in the relatively near-term future. In particular, superconductors may play a key role in the development of a space-based strategic defensive system.

We can categorize applications into three general classifications, based on whether the size of the superconductor is small, medium, or large scale. The first major application area which we examine is the domain of microelectronics. Superconductive "wiring" between circuit elements packaged in integrated circuit chips would reduce heat dissipation and enhance circuit speed.

A superconducting microelectronic device, known as a Josephson junction, displays properties similar to those of a transistor. The Josephson junction consists of two thin wafers of superconducting material separated by a thin region of normal conductor (other basic designs are possible also). This device has important potential for application as logic elements in computer circuits because it can function as a switch between two different states. These states, or modes of conduction, are distinguished by the presence or absence of a tunneling super current through the thin "barrier" of normal conductor. These states can be controlled by varying the amount of current through the junction or by varying a magnetic field around the junction.

The major advantages afforded by these superconducting devices over more conventional semiconductor-based logic elements are their low heat dissipation and their high switching speeds (roughly 10 times faster than the fastest conventional semiconductor switches). Very low power consumption implies the potential for very dense packaging of superconducting circuit elements into integrated circuits, which in turn implies faster computers since signal transit time between components can be minimized.

Josephson junctions at very low temperatures have already been used in electronic circuitry, and the recently

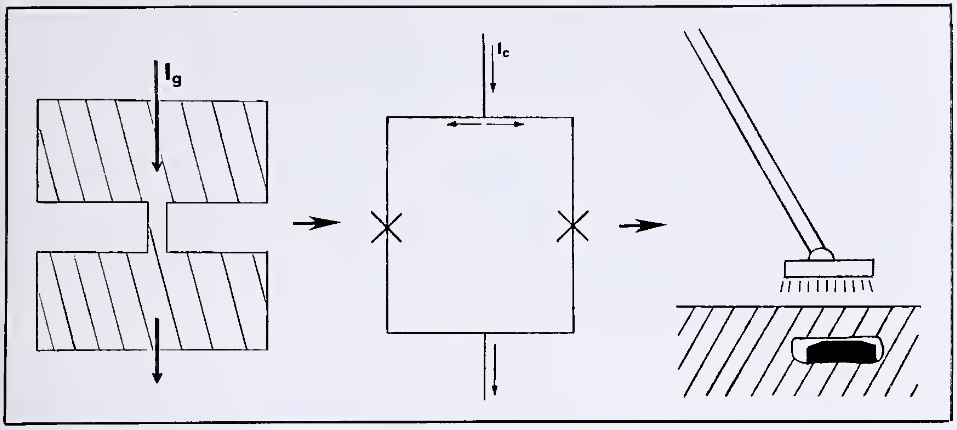

Figure 5. A Josephson junction (left) can be utilized in a SQUID (center) to yield high magnetic sensitivity for the detection of mines (right).

discovered materials will reduce the expense and sophistication required for their implementation.

Room temperature Josephson junction devices would have a dramatic impact on both commercial and military computer systems. Experts talk suggestively about the achievement of computer power equivalent to today's mainframes but packaged in systems about the size of current personal computers, operating without any need for refrigeration. Clearly, the strategic significance of such capabilities are enormous, with impact on avionics and vetronics, "smart" munitions, communications systems, C3I and administrative/logistical computer systems, and many many others. Indeed, the computing power required for battle management of a diverse strategic defense initiative (SDI) architecture may be realized by superconducting supercomputers.

Josephson junctions can perform other electronic functions in addition to their digital circuit applications. Their ability to function as oscillators generating high frequency signals make them suitable candidates for millimeter and submillimeter wave electronic circuitry. The military's interest in communication and radar systems operating in this high frequency domain make superconducting electronics an exciting research frontier with great technological potential.

Another important property of the Josephson junction is its very high sensitivity to magnetic fields. Sensitivity to changes in magnetic flux can be enhanced by forming a superconducting loop which links two Josephson junctions. Such a device is known as a "SQUID" (Superconducting Quantum Interference Device) or (less poetically) as a Josephson interferometer.

The junction's exceptional characteristics make it a highly sensitive sensor of electromagnetic radiation. Such sensors are valuable devices in fields as diverse as medical diagnostics (in Nuclear Magnetic Resonance Tomography and Nuclear Magnetic Imaging Systems); physics, geophysical, and radiosatronomical research; and medical research (magnetically mapping brain activity). Military applications include potential use of Josephson junction devices in microwave and infrared detectors (such as for sensors in an SDI system) and in the detection of mines and submarines (see Figure 5).

By combining the high sensitivity of SQUIDs and the magnetic shielding ability of a room made of superconducting material, extremely faint magnetic signals can be studied. One fascinating application in this area is the investigation of signals in the brain itself; thus, superconductors may play a vital role in helping man understand the complex workings of the human mind.

Medium scale applications include incorporation of superconductors into compact electric motors and generators. The primary advantages to be realized are greater energy efficiency and higher current handling capacity. Another medium scale application involves use of superconductors to perform magnetic separation of different materials, such as in the processing of ores.

Large scale applications of superconductors include electric power generation, storage, and transmission, and the production of high strength magnetic fields. The ability to carry huge currents without heat dissipation make superconducting magnets far more advantageous than conventional magnets. High magnetic field applications include the potential use of superconducting magnets in the Superconducting Super Collider (the SSC, a multi-billion dollar high-energy physics research facility) and in the creation of intense magnetic fields necessary to confine plasmas at enormous temperatures in fusion reactors.

One large scale military application is the electromagnetic rail gun, which can use superconducting magnets to generate the high fields necessary to propel a projectile at very high velocity. Such a device is under study as a possible component in a strategic defense system, and the Army is interested in the potential development of sufficiently com-

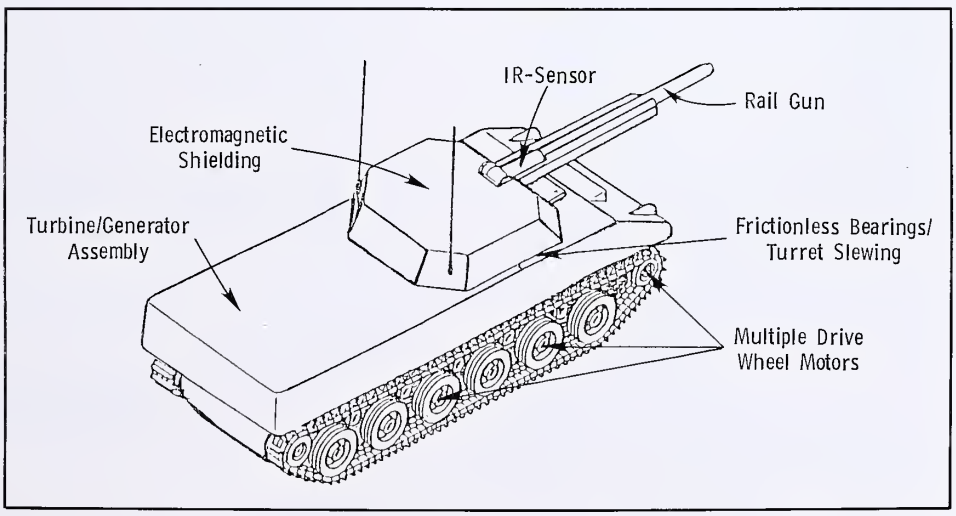

Figure 6. Superconductors in a Notional Armor System.

pact rail guns for fielding in armored vehicles. Particle beam weapons and the free electron laser can also benefit from high magnetic field technology.

The magnetically levitated train will require superconducting magnets, and the military may be interested in tactically deployable "maglev track" systems for heavy load transport at logistical and maintenance field facilities. Indeed, there is even the prospect of magnetically levitating tank turrets to achieve fast slewing rates. Figure 6 illustrates a number of superconductor applications which might be incorporated into future tanks.

Most all of the applications we have cited are extrapolations of "old" ideas for using superconductors; they merely replace the previous low temperature superconductors with the new high temperature materials. It is probably safe to say that many exciting concepts for novel superconductor applications have yet to be conceived.

The Army's Players

Several laboratories of the U.S. Army Laboratory Command are involved in research related to developing and understanding the new ceramic superconducting materials and incorporating them into future Army systems.

A key player in the Army's development of superconducting materials is the Materials Technology Laboratory (MTL) in Watertown, MA. The MTL research effort focuses on the synthesis, processing and characterization of high temperature superconductors. The Materials Science Branch is currently synthesizing materials in both the Nickel and Copper systems. The Ceramics Branch effort centers on processing technology, including crystal growth, hot pressing, and thin film deposition. Work investigating optical properties and new mechanisms for superconductivity is also in progress.

Research related to applying this new technology in future Army systems is being conducted at the Electronics Technology and Devices Laboratory (ETDL), Fort Monmouth, NJ, and at the Harry Diamond Laboratory (HDL), Adelphi, MD. The first applications of the new ceramic superconductors are expected to be in the area of microelectronics, and ETDL is already studying device applications such as high precision tuning elements; millimeter wave, infrared, and optical sensors; and portable generators. HDL is also at work in the areas of theory, microwave properties, and radiation susceptibility.

Other agencies within DA and DOD are pursuing research efforts into superconductivity and its potential applications. In particular, the Army's Strategic Defense Command and the Army Research Office are actively working to study this new technology and to pioneer militarily useful applications. These various organizations, by working together, can exploit many synergies in their joint venture to develop superconductor technology for defense applications.

Summary

The past year has seen major advances and great excitement in the science of superconductivity, but it will require many further advances to realize the great potential which this technology promises.

The race towards room temperature superconductors is underway. Recent experimental results suggest that this goal may be achievable, since transient signs of superconductor-like behavior at (and above) room temperature have already been observed in the laboratory.

As with other infant technologies (such as the transistor and the laser), many important applications of superconductor technology may not yet even be conceptualized. Indeed, as members of the Army's research, development and acquisition community, we should all strive to better understand this new technology and to contribute to the development of new concepts for its application.

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Army Leadership Discusses International Armaments Cooperation

The senior Army leadership met on Dec. 17, 1987, at Headquarters, U.S. Army Materiel Command to discuss international armaments cooperation with representatives from OSD, our allies and U.S. industry.

The changes in global relationships coupled with shrinking military budgets, both here and abroad, have given new impetus to the need for collaboration in armaments development between the U.S. Army and our allies. OSD representatives stated that international armaments cooperation is growing and is evident in almost every aspect of our materiel modernization program.

Our allies discussed the need for continued growth in our cooperative efforts if we are to deploy technologically advanced systems at their lowest cost. Armaments cooperation is seen as fundamental to strengthening our alliances. The U.S. industry representative focused on industry awareness of the improved technologies available from our allies, the need to meet our national security requirements from a broader base, and the advantages to U.S. industry resulting from cooperation with overseas businesses.

The conferees were challenged to seek innovative and better ways to take advantage of our allies' research and development efforts and to look at them as a means of keeping pace with our modernization requirements.

MANPRINT Implementation in the Materiel Acquisition Process

By Warren Theis

The need to consider the soldier in the total system definition has always been a requirement in the Army. During the early 1980s, senior Army leadership determined that the Materiel Acquisition Decision Process (MADP) should include a greater emphasis on the soldier's performance and reliability capabilities. This emphasis became known as the Manpower and Personnel Integration (MANPRINT) concept in the Army.

The Army has defined MANPRINT to include six distinct functional domains: Human Factors Engineering (HFE), Health Hazards, System Safety, Manpower, Personnel and Training. Because these domains cut across many Army organizational responsibilities, MANPRINT requires an integrated effort by the materiel developer — the Army Materiel Command (AMC), and the combat developer — the Training and Doctrine Command (TRADOC). Overall leadership is provided by the Office, Deputy Chief of Staff for Personnel (ODCSPER) at HQ Department of the Army.

The recent thrust of MANPRINT is to implement it into the MADP, which requires a total Army and industry effort. This article focuses on the role AMC has played in policy formulation and field implementation. Particular attention is devoted to the treatment of MANPRINT in source selection.

Policy Formulation. A new Army Regulation AR 602-2, MANPRINT in Materiel Acquisition Process, has been in effect since April 1987. AMC plays a major role in preparation and coordination of regulations, circulars, pamphlets, primers, guides and handbooks that cover the "how to do" actions of MANPRINT implementation into the MADP. Many of these documents are under revision based on recommendations from field elements and actual implementation experience. Suffice it to say, the basic policy is in place.

Field Implementation. It is clear that MANPRINT is starting to take hold throughout the materiel acquisition process. The conclusion is supported by the appearance of MANPRINT considerations in requirements documents, soldier-in-the-loop testing, concerns being raised at decision reviews and MANPRINT evaluation criteria in the source selection process.

With increasing frequency, we see that MANPRINT is being properly addressed in system and development specifications, in Statements of Work (SOW), in the selection of Data Item Description and as source selection evaluation criteria. MANPRINT is also being highlighted in the Executive Summary of Requests for Proposal (RFP) to make clear to the chief executive officers that MANPRINT counts.

MANPRINT is showing up more and more as a discriminator in program decisions, determining if nondevelopmental items (NDI) acquisition strategies are viable, and is being vigorously pursued during contract execution. MANPRINT experts have been working with their industry counterparts in assuring a sound MANPRINT management and engineering process has been integrated into the developmental effort. The key AMC individuals that make it happen are the MANPRINT advocates (previously known as managers) located at each major subordinate command and their counterparts within program management offices and industry.

AMC efforts to expand MANPRINT awareness have resulted in bimonthly video conferences, road show briefings

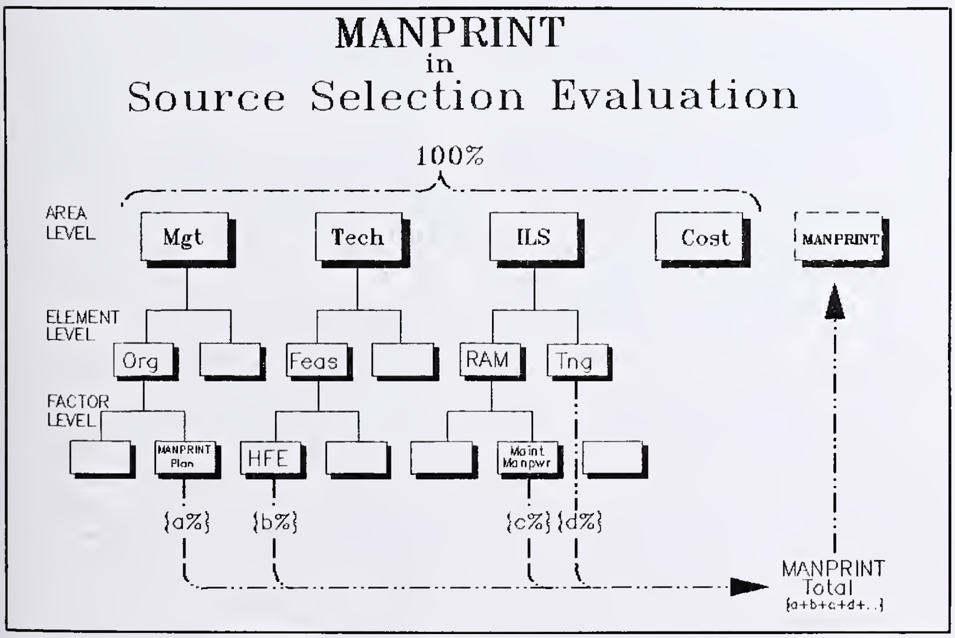

Figure 1.

	TOTAL THRU FY87	FY88
	(Personnel Attended)	
GO/SES (1 day)	78	
		13*
Mid-Manager (1 wk)	134	
Staff Officers (3 wk)	103	6
Local Special Training	130	0
AMC MANPRINT Seminar		85

Table 1.

to AMC commanders, a CG AMC sponsored seminar to AMC commanders/senior managers (Dec. 16, 1987), CG AMC briefings to industry at Atlanta Conferences and participation of senior AMC personnel at Army-industry MANPRINT roundtable meetings, and published articles in appropriate journals. It is clearly essential to have strong sponsorship from high level Army leadership in implementing MANPRINT.

Formal MANPRINT training has been completed by hundreds of AMC personnel at all levels from general officer/Senior Executive Service (GO/SES) to action officer level. AMC has participated heavily in the Army approved MANPRINT senior officer, mid manager and action officer level courses. The MANPRINT advocates at the major subordinate commands have also sponsored and personally provided local training to their personnel and collocated PM personnel. We have found the greatest shortcoming for training in AMC has been the lack of on-site training for large numbers of AMC personnel. AMC is working with TRADOC to expand the number of Army approved courses and is investigating an in-house capability for a on-site AMC MANPRINT training program through the Army Logistics Management College.

A long term goal is to build an inhouse government capability to meet the AMC need for training. Progress toward this goal is dependent upon the outcome and success achieved in the Army MANPRINT Senior Training Course. AMC has already accomplished considerable training as shown in Table 1.

The asterisk in Table 1 denotes that the General Officer/Senior Executive Service (GO/SES) and mid-managers courses were merged effective FY88 and called the MANPRINT Senior Training Course (one week). This course and the MANPRINT Staff Officers Course (three weeks) are also open to any industry personnel. They are both highly recommended, particularly for contractors actively engaged in weapon system design, development and acquisition. Course information is available from the Soldier Support Center-National Capital Region, W. Ashley or SGT Usher at Area Code 202-325-3706.

Typical MANPRINT execution/compliance activities include:

• *Utilization of the Materiel Acquisition Review Board (MARB).* MARBs are held at the major subordinate command sites as the weapon systems proceed to decision milestone reviews. The purpose is to review program and documentation to ensure the system is ready for senior Army decision review. The MARB reviews, which apply to major and non-major systems and for Program Executive Office (PEO) programs, are normally co-chaired by the MSC commander and the PEO/PM. The deputy commanding general for research, development and acquisition at HQ AMC recently challenged the MSC commanders to be certain MANPRINT considerations are given full visibility at the MARBs.

• *AMC experts working hand-in-hand with the TRADOC-chaired MANPRINT Joint Working Group (MJWG).* The MJWG identifies tasks and documents the overall MANPRINT plan for the system in the System MANPRINT Management Plan (SMMP). The fact that the MJWG normally develops the SMMP in parallel with the requirements documents ensures MANPRINT constraints are recognized early.

• *MANPRINT evaluations as a part of the Independent Research and Development project evaluation process at the AMC major subordinate commands as well as technical, cost and other criteria.*

• *The AMC test community, Test and Evaluation Command (TECOM) and Army Materiel Systems Analysis Activity (AMSAA) to ensure MANPRINT considerations are incorporated in technical testing, independent evaluation reports/plans, and test design plans as well as coordinating with the user testing community.* TECOM and AMSAA both use the Required Operational Capability, Test Evaluation Master Plan, SMMP, and Integrated Logistic Support Plan as appropriate data sources to develop the various test plans and reports. AMSAA supports MANPRINT by providing representatives to serve on the MJWG, Source Selection Evaluation Board (SSEB), Integrated Logistic Support Management Team, Test Integration Working Group, Logistics Support Analysis/Log Support Analysis Record Reviews, RAM scoring conferences and system design reviews.

• *A MANPRINT data base, currently in final stages of development by the Materiel Readiness Support Activity.* The centralized data base will contain weapon system data from each domain of MANPRINT. Users such as the PEO/PM, AMC, and TRADOC and industry will use data for conducting Hardware and Manpower Analyses, Human Factors Engineering Analysis (HFEA) and other front-end analyses required for major decision reviews. The data base is planned to be operational by September 1988 for 93 weapon systems. Data for these 93 systems will be applicable to similar follow-on systems.

This topic calls for special attention due to the importance of communicating MANPRINT concerns in RFPs to industry. While this topic has been controversial in the past, HQDA and AMC worked together to settle the issues which culminated in Army policy guidance established by the under secretary of the Army.

AMC's policy is that MANPRINT should be considered in all procurements; i.e., major and non-major system,

developmental and nondevelopmental items, competitive and non-competitive procurements. As the CG AMC previously stated, "Each system inherently has a unique level of MANPRINT consideration, ranging from very little to considerable. Do MANPRINT whenever we stand to gain something from it and we can afford to pay for that something."

MANPRINT is being incorporated into the source selection process using the foundation policy guidance stated in the under secretary of the Army message of June 16, 1987 on the subject of Policy for MANPRINT in Source Selection for Major Systems and Designated Acquisition Programs. The message described the treatment of MANPRINT in the solicitation (specification and statement-of-work), evaluation criteria, structure of the Source Selection Evaluation Board, evaluation report and exceptions to policy.

AMC has interpreted the key theme of the under secretary's guidance to be "integration" and "increased visibility."

Integration. The evaluation of MANPRINT criteria is structured so that MANPRINT considerations are included as elements, factors or subfactors in each and every area of proposal evaluation as appropriate to the acquisition.

Increased Visibility. This will be achieved by:

- Assuring that the SSEB shall prepare an integrated assessment of how MANPRINT was addressed in all evaluation areas and provide it to the Source Selection Authority (SSA).
- Structuring the SSEB to establish and maintain MANPRINT visibility.
- Making MANPRINT an entity at first level of organization.

A notional example of AMC's interpretation of the under secretary's theme is shown in Figure 1.

AMC's interpretation is being incorporated into contractual policy requirements by an Army Federal Acquisition Regulation Supplement to be issued soon. We believe this language and interpretation gives MANPRINT visibility equal to that of any other evaluation area level criteria without legislating a precise approach. It clarifies how MANPRINT can be considered an entity and also a subset of other evaluation areas without double weighting the same aspect in the evaluation. Recent application of this policy approach has been accomplished in the Forward Area Air Defense Line-of-Sight, Forward Heavy source selection evaluation criteria (Fig 2).

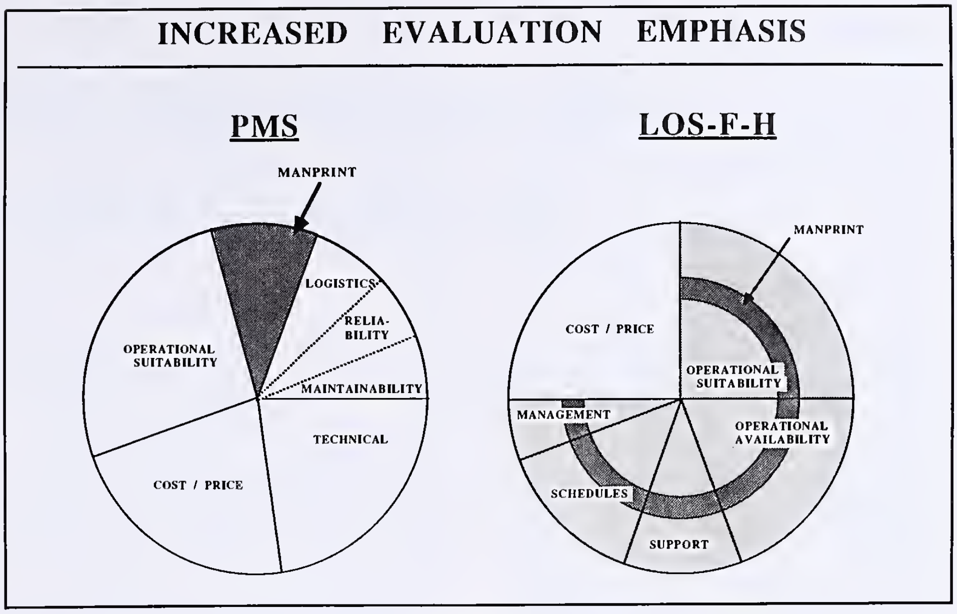

Figure 2.

AMC pamphlet 715-3, The Source Selection Process, Vol I & II provides an excellent description of the source selection process and procedures. An example shown in AMCP 715-3 Volume I, Appendix I, pages 84-90, describes a typical application of the integration of MANPRINT as an evaluation criteria across appropriate levels of evaluation in consonance with the under secretary of the Army policy (see Fig. 3). MANPRINT considerations are included within the area level criteria of operational suitability, logistics, technical, and cost.

Another way that has also proven to be successful is for the Source Selection Authority (SSA) to establish MANPRINT as a separate area level evaluation criteria and remain within the above policy guidance. Care should be taken to ensure double weighting of common MANPRINT, Technical, ILS, or other considerations does not occur.

Paragraph 4-13a in Volume I of AMC Pamphlet 715-3 states that "When any criteria is so critical to system performance that it is of overriding importance it should be split up, with the approval of the Source Selection Advi-

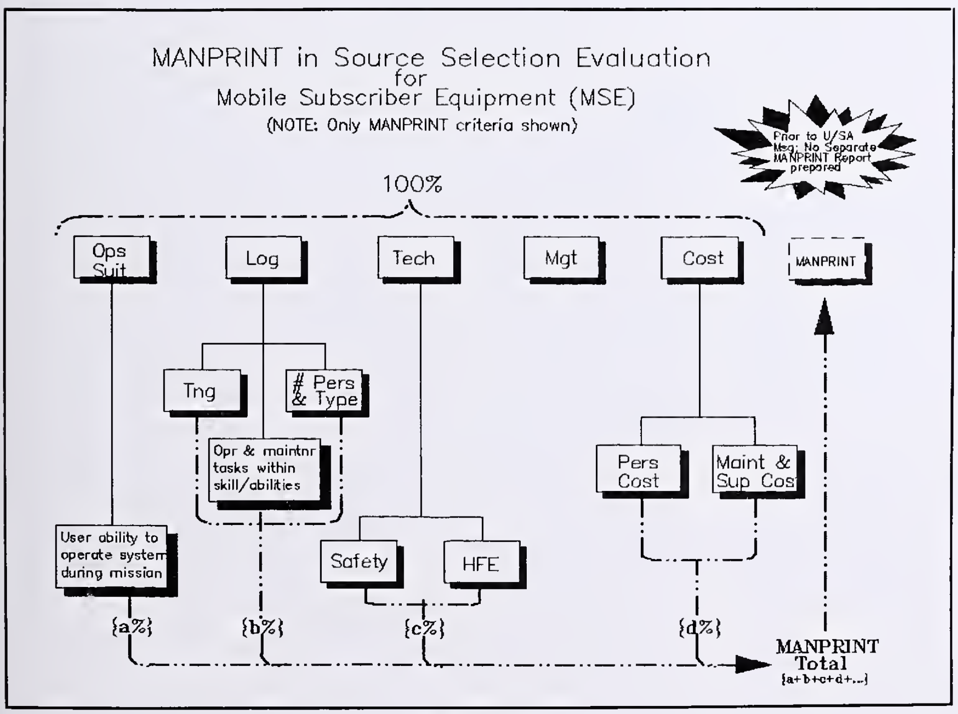

Figure 3.

sory Council (SSAC) and the SSA, and its detailed treatment established separately so there can be no question of how it will be evaluated at any level of evaluation." This can be interpreted as allowing MANPRINT to be evaluated separately at the area level.

AMC has also published a "how to" Pamphlet, AMCP 602-1, to translate MANPRINT considerations from the requirements documents to the Requests-for-Proposal. The currently published AMCP 602-1 deals with government developed systems. Another Pamphlet, AMCP 602-2, for non-developmental items is under preparation and is expected to be published by April 88. Both are being referenced in the Army MANPRINT training courses. Copies are available from HQ AMC, AMCDE-PQ.

This article provides a brief indication of the scope and breadth of AMC's MANPRINT implementation effort. There are numerous other important efforts within AMC major subordinate commands and organizations not discussed in this article. These efforts may be addressed in future publications.

In closing, HQ AMC's implementation efforts in the future will focus and emphasize communication, policy updating, MANPRINT training, participation in the MANPRINT Joint Working Group, MANPRINT evaluation of Independent Research and Development projects, testing, and involvement of MANPRINT in the procurement and source selection process. Proactive incorporation of MANPRINT considerations in the requirements, design, solicitation, source selection and testing processes must continue to be emphasized in the field by the major subordinate commands, PEO/PMs, TRADOC schools and industry. This will result in "Soldier and Unit Performance Enhancement," which is one of five key operational capabilities identified by the Army.

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Belvoir Works on Close Combat Decoys

The U.S. Army Belvoir Research, Development and Engineering Center is currently working on a series of multispectral close combat decoys that very closely replicate various weapon systems. The decoys consist of a painted fabric skin stretched over a collapsible frame. In operation, the decoys can be used to draw enemy fire which enables our forces to counterattack.

Other decoys will mimic vehicles and equipment common to logistics operations and field command posts. They will give a false picture of our intentions in order to delay and disrupt enemy intelligence.

The center is also working with the Army's Communications-Electronics Command, the Missile Command and the Laboratory Command on an integrated program to study the complete spectrum of threat sensors and deception.

During the past year, the center has evaluated systems ranging from simple billboard tank decoys to complex communications systems. These evaluations were so successful that the Army has directed immediate limited acquisition and fielding of four decoy systems. Projected fielding of these systems is to be completed within two years.

Decoys and battlefield deception are becoming an increasingly important part of the center's countersurveillance and deception program. However, camouflage, which is also a prominent factor in preventing the enemy from knowing our intentions, is the center's second major thrust area with this project.

A new three-color camouflage pattern is being developed to replace the four-color pattern in use since 1974. This new system psychologically disrupts the image's shape and perimeters to the viewer's eye. Broad bands of black are used to break up the straight lines and sharp corners that make a man-made object stand out from its more irregular natural surroundings.

Converting to the new three-color pattern is a major undertaking. The transition's difficulty is eased by the center's use of computer technology which creates the new camouflage designs in a fraction of the conventional drafting time. The computer system can create scale drawings and develop camouflage patterns for specific pieces of equipment using a simple photograph as a reference.

When the camouflage patterns are designed they are painted onto equipment with special coating resistant to chemical warfare agents. These agents must also meet EPA environmental standards. Eventually, Army camouflage experts hope to combine the computerized pattern production technique with robotic technology to automatically paint equipment.

In addition to disruptive-paint patterns, camouflage nets have also been designed to conceal Army vehicles and equipment. Their versatile, flexible form allows several nets to be joined together forming tailor-made nets for concealing large or irregularly shaped equipment or for their individual use. Special radar reflecting materials built into the net fabric provide additional protection.

Camouflage nets can be used for equipment of very large or small dimensions and have also been designed to protect the Army's most valuable resource — its soldiers. A five by seven-foot version of the larger nets was developed at the request of the 9th Infantry Division and the Army Development and Employment Agency to protect individual soldiers in the field. These nets may be folded to pocket size for carrying ease. Individual nets are used to conceal fighting positions or weapon emplacements. Recent testing of the individual nets was very successful in Korea and other overseas locations.

These high-tech developments are made possible by the center's advanced facilities. The center's radar test arch is used to test the radar reflecting qualities of various materials used for the camouflage developments. This unique facility uses three-dimensional scale models to locate radar "hot spots" requiring additional camouflage protection or redesign. It is also used to measure the effectiveness of already developed camouflage materials.

The center's camouflage developments have the potential of saving thousands of lives and billions of dollars in equipment. This makes it a very worthwhile investment.

A New Approach to Troubleshooting

By Joseph W. Steyaert and Joseph A. Herman Jr.

Introduction

An increasing complex arena of military vehicle maintenance confronts today's mechanic with a number of difficult maintenance decisions. The choices the mechanic makes impact on both the time required and the quality of the diagnosis and repair. Bulky manuals, conflicting training procedures, complicated automatic test equipment (ATE), and increasing sophisticated vehicles are just a few of the problems which have an impact on the mechanic's decisions.

The Artificial Intelligence Job Performance Aid (AIJPA) is being developed to aid the mechanic and improve the overall readiness of the Army's vehicle fleet. The AIJPA is a portable diagnostic troubleshooting aid, used by mechanics of varying skill levels, which features a "voice in/voice out" man-machine interface. This interface allows the mechanic to carry out diagnostic and repair tasks in a "conversational" mode with the system.

AIJPA Hardware

The AIJPA hardware consists of a personal computer (PC) and the radio frequency (RF) equipment. The PC is an IBM compatible system equipped with dual floppy disk drives, a commercial speech board, and software developed for Phase I of the program.

When the AIJPA RF equipment was designed, the initial version was an off-the-shelf system, but its squelching between the receive and transmit modes made it impossible to transmit the leading consonant of a spoken word. Because of this limited ability to transmit, the off-the-shelf technology was dropped in favor of a system made to meet the AIJPA requirements.

The current system performs continuous transmission and reception while providing an extensive communications range (up to 200 feet line-of-sight) with a high-quality transmission and reception signal.

The RF equipment consists of a headset with noise-filtering microphone, an earpiece, and a wireless transceiver which can be clipped onto a belt or shirt pocket.

The Phase II hardware will be slightly different. The PC will be ruggedized, commercial equipment which will be lighter and smaller and provide the maximum demonstration capability. The main purpose for the development of this prototype system is to obtain a readily portable demonstrator that can be taken out to the field for user validation/verification at any time.

High-Storage capacity memory components, such as Compact Disk Read Only Memory, are being considered for possible inclusion in the system. A mini-keypad is to be placed on the transceiver to allow manual input of test data and provide a secondary means of inputting commands to the system if it becomes inconvenient or impractical to use the voice in/voice out communication.

AIJPA Software

The AIJPA software, primarily written in PROLOG (Programming in Logic), was developed in Phase I for the High-Mobility Multipurpose Wheeled Vehicle (HMMWV) electrical system (battery, starter, alternator, etc.). PROLOG was chosen for the initial prototype language because of the high level of design flexibility and programming freedom it allows. The knowledge base was established by gathering the information from the organizational (-20) vehicle technical manuals and various experts in the maintenance arena.

The HMMWV -20 manual, written in an artificial intelligence (AI) format under a previous contract, was perfectly suited to the prototype development. The AI format was achieved by taking the diagnostic and repair text in the -20 manual and converting it to rules.

A backward-chaining inference strategy was employed which allowed the rules to be organized into fault tree logic. Backward-chaining inference is an AI strategy whereby the system starts with a goal to be proven and tries to establish the facts needed to substantiate the goal.

The AIJPA starts out by asking some simple questions and the mechanic's responses are used to trigger more specific questions which lead to the diagnosis of the faults. Once the fault has been pinpointed, the repair sequence is given and, if multiple faults exist, the system continues.

The AIJPA Probabilistic Decision Algorithm (PDA) is the "brain" of the AIJPA system. As with other expert systems, the algorithm works with lists and linked-lists in order to obtain its information. A distinguishing feature of the AIJPA PDA is its use of fault-causal probabilities in the diagnostic process which makes it more than a computerized manual. It approaches the problem of diagnosing and troubleshooting from the perspective of the expert mechanic rather than from a procedural rule book.

One of the most important aspects of an expert system is the feed-back loop which enables the system to "learn" from mistakes to improve its effectiveness over time. If the PDA misdiagnoses a problem, it "learns" by using the information received during the diagnostic process to modify its own probability lists to include the new information.

The Phase II software will be further developed to include complete fault diagnosis and repair, as stated in the -20 manuals of the HMMWV and the Commercial Utility Cargo Vehicle (CUCV). Although the CUCV -20 manuals have not been converted to an AI format, the CUCV was a logical candidate as the next vehicle for the AIJPA application because of its distinct similarities to the HMMWV power train and other major systems.

Design Features

The voice in/voice out feature provided by the RF equipment allows the maintenance personnel to proceed through the diagnosis and repair sequence without having to stand at a terminal and read from a screen. Instead, a mechanic is free to move around the vehicle to visually examine the affected part and carry out the diagnostic/repair procedure. The mechanic's movement is unencumbered by cords because of the wireless RF transceiver.

The AIJPA acts as an expert assistant offering diagnostics, training, and logistics support. The system "talks" the mechanic through the maintenance action using the information from its knowledge base and measured test data. Each step of the sequence is stored in the AIJPA memory and the whole sequence can be recalled as a training lesson, when needed.

Logistics support can be simplified by using the AIJPA. The vehicle serial number is entered on the AIJPA when the diagnostic process is started, along with the vehicle type. Once the diagnostics are completed, a list of replacement parts can be printed out complete with part numbers, since the vehicle type and serial number are known.

Automatic test equipment has been developed by the Army for a number of vehicle systems and components. The AIJPA has a serial interface which allows it to communicate with the ATE. This interface allows the ATE measured values to be read by the AIJPA for use in the diagnostic procedure. It should be noted that although the AIJPA can be used along with the ATE, it also has a manual input keypad which can be used to input values from manual test equipment such as voltmeters or gauges.

The AIJPA adjusts its presentation level to the skill of the mechanic. The mechanic inputs his identification number which enables the systems to raise, lower, or maintain the skill level being presented. If another mechanic has to finish a job already in progress, he merely inputs his identification number to trigger the skill level adjustment, then proceeds to finish the job.

The basic AIJPA hardware is independent of the vehicle undergoing diagnostic evaluation. No changes are required for the hardware configuration which acts as a house in which the vehicle-particular diagnostic and repair software resides. In fact, once the complete diagnostic package for a vehicle is completed, only minor software modifications will be necessary to develop the package for another vehicle. This is because all vehicles are comprised of the same major systems, i.e., electrical, hydraulic, fuel, transmission etc., which differ only in the areas of size, weight, and level of performance, not in the primary system function.

The computer graphics used on the AIJPA are object-oriented. This means that instead of storing complete pictures, the pictures are stored in group of line segments, circles, and other basic geometric figures. These basic figures can be manipulated to produce any picture in a more efficient manner when compared to the large amount of storage space required for a complete picture. Although this feature was only demonstrated in Phase I, it is expected to be used throughout the software development of Phase II.

Built-in self-testing is included with the AIJPA. The system runs through a series of self-checks when it is turned on to ensure proper performance throughout the diagnostic and repair sequence.

The AIJPA is portable, simple, and rugged. The original version of the prototype weighs 55 pounds, not including the headset and transceiver. The Phase II demonstrator will weigh 35 pounds, again without the headset and receiver, and will be compact enough for storage under an airplane seat. The demonstrator will also be ruggedized to enable it to withstand the wear and tear it will encounter during validation and verification.

Program Status

The Phase II contract was awarded on Sept. 4, 1987. Currently, most of the hardware has been assembled for the software development by the contractor. The software is being focused on an enhancement of the user interface and the investigation of speech synthesizing software. The remainder of the development hardware will be acquired in early 1988.

Once all of the hardware is acquired, the software development will focus on the expansion of the Phase I capability to include the diagnostic and repair data for all of the systems on both the HMMWV and the CUCV. When the software development is completed, the AIJPA will undergo user validation/verification. The two-year effort is scheduled to be completed in later 1989. Field demonstration will then commence, with system fielding to be determined by user reaction and acceptance.

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JOSEPH A. HERMAN JR. is a project engineer who works on AI/expert systems programs for the Diagnostic Branch of the Vetronics Division at the U.S. Army Task-Automotive Command. He has a B.S. degree in mechanical engineering from Wayne State University.

Career Management Personnel

The following is a current list of career managers for Skill 6T (Materiel Acquisition Management), and Functional Areas 51 (R&D), 52 (Nuclear Weapons), and 97 (Contracting and Industrial Management).

Proponency Managers:

- LTC Daniel D. Ziomek (Skill 6T), HQ AMC, AV 284-5076
- Jim Coats (Skill 6T), HQ AMC, AV 284-5076
- Jo Laree Green/CPT James E. Forsyth Jr. (FA 51), HQ AMC, AV 284-8537
- CPT Frank R. Mann (FA 52), Ft. Leavenworth, KS, AV 552-2724
- COL Al Greenhouse (FA 97), U.S. Army Contract Support Agency, SARDA, AV 289-2782

MILPERCEN Professional Development/Assignment Personnel:

- Barbara Head (Skill 6T Assignment Officer), AV 221-3125
- MAJ Ed Coughlin (FA 51 Assignment Officer), AV 221-3125
- MAJ James "Jay" Moore (FA 52 Assignment Officer — Company and Field Grade Assignments), AV 221-3116/7
- LTC Leo J. Baxter (FA 52 Assignment Officer — Colonel Assignments), AV 221-7862
- MAJ Craig N. Robinson (FA 97 Assignment Officer), AV 221-3125

The Development of RUSKII For Computer Assisted Translation

By CPT Robert M. Serino, Dr. LeRoy D. Moyer, and John M. Jacoby

Introduction

The widespread availability of personal computers in the last several years has had a profound influence on day-to-day operations in both the public and the private sectors. Personal computers afford time-saving and cost-effective control of information for activities ranging from word processing and data base management to mathematical calculating. Not surprisingly, the use of personal computers has been growing as steadily in the U.S. Army as in the private sector.

In the next few paragraphs, we will discuss the motivation, execution, and results of a recent development project at the U.S. Army Foreign Science and Technology Center (FSTC) known as "RUSKII." This effort yielded a unique family of personal computer software that was designed, developed, and fielded to over 200 diverse U.S. government agency users for the purpose of "lowering the foreign language translation barrier."

We hope that this article will demonstrate to others that it is possible to achieve, through practical mechanisms, technical objectives that may at first seem unreachable.

The development project known as RUSKII essentially began in December 1985, when FSTC acquired over 50 IBM-compatible personal computers for use by scientific and technical analysts to streamline and facilitate production efforts.

In accordance with command guidance to maximize the production enhancement potential of the personal computers, we investigated the possibility of developing a computerized capability to speed up or "catalyze" foreign language translation for military-critical languages such as Russian; that is, we set out to provide people skilled in a science or a technology, but not necessarily in a foreign language, with a speedy capability to decipher simple components of foreign language documents such as titles, tables, and short paragraphs using a personal computer. The capability could later be a practical means for insuring the cost-effectiveness of a complete professional translation.

Implementation

Initial efforts to develop RUSKII involved a team consisting of two: one person working on the development of the data base, and the other working on the development of the software to manipulate the data base. After some discussion, research, trial, and error, it was decided to write the software in Basic computer language, and to use Cyrillic transliteration as the means of loading and retrieving Russian terms through the computer keyboard. Twelve months later, the first version of RUSKII (1.0) was completed.

Suitable for use in IBM-compatible personal computers, the working software consisted of two 5-1/4-inch floppy disks containing an operating program, a 15,000-term vocabulary, and a translating file for assembling, storing, and retrieving strings of individually translated terms.

Several months after the completion of RUSKII 1.0, a third person, who was skilled in Pascal computer language, joined the project team. Utilizing his expertise, the team wrote a new Pascal-language version of RUSKII (version 2.0) that operated approximately three times faster than the original Basic-language version.

Although the new software was also IBM-compatible, it required a minimum of 512 kilobytes of random access memory (RAM) to operate. Despite the larger memory requirement, RUSKII 2.0 offered a great potential for multi-language capability because the double-disk software had the operating program on one disk and the data base of foreign language terms on the other disk. (By comparison, version 1.0 maintained the language data base on both disks.)

Concurrent with the development and subsequent issue of RUSKII 2.0, team members became aware that users also wanted supplements in other languages such as German, French, and Spanish.

Although language expansion seemed technologically reasonable, it was apparent that a significant amount of additional time would be necessary to construct the additional foreign language data bases. Thus, the expansion would require additional resources, including the availability of a temporary position, and the availability of facilities and equipment on a loan basis for up to 18 months.

Before the RUSKII expansion began, several issues surfaced concerning people, qualifications, and priorities. The people and qualification issues were resolved by hiring local graduate students of foreign languages from the University of Virginia, Charlottesville.

Graduate student participation in this project seemed to work quite well for several reasons. First, there were sufficient qualified people willing to participate in the project on a part-time basis. Second, employing graduate students

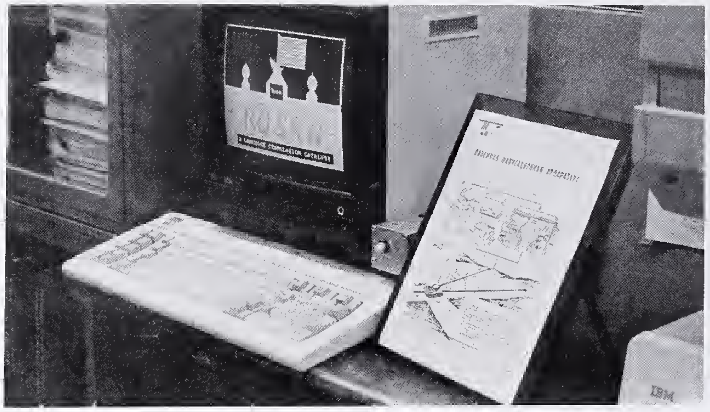

Figure 1. "RUSKII" ready to operate.

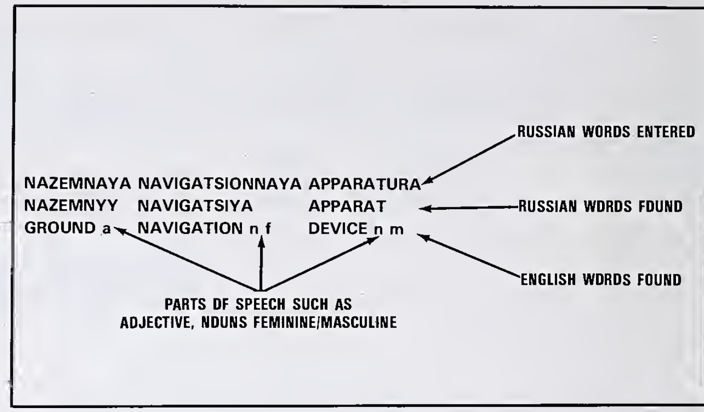

Figure 3. Printout of Document Titled "Ground Navigation Device" as shown in Figure 2.

RUSSIAN:	А	Б	В	Г	Д	Е	Ж	З	И	Й	К	Л	М	Н	О	П	Р	С	Т	У	Ф	Х	Ц	Ч	Ш	Щ	Ъ	Ы	Ь	Э	Ю	Я
ROMAN:	A	B	V	G	D	E	ZH	Z	I	Y	K	L	M	N	O	P	R	S	T	U	F	KH	TS	CH	SH	SHCH	"	Y	'	E	YU	YA

Figure 2. Transliteration System for Russian Cyrillic.

further demonstrated FSTC's commitment to strengthening the good relations so necessary in a university community like Charlottesville. Third, the RUSKII project provided students with an opportunity to undertake creative and mutually beneficial work, mutually beneficial in that the language expansion also improved the students' vocabularies.

Priorities for follow-on languages in the RUSKII expansion were established by determining the relative proportion of foreign languages in the FSTC library's journals in the context of military need. Based on this process, German was selected as the first language to be added, followed by French and Spanish.

In July 1986, two graduate students began constructing a RUSKII supplement in German. Initially, based on the English terms contained in the Russian data base, this supplement represented the first use of graduate students on the project.

Despite some initial "teething" difficulties, the German supplement was completed within 12 months. In a similar fashion, four graduate students began work to develop a French-language supplement to RUSKII in the fall of 1986. That version was later completed in June 1987. After putting the finishing touches on the French and German supplements, attention turned to developing a Spanish-language version 2.0. The Spanish supplement was completed by the end of 1987.

Results and Discussion

Thus far, four separate language versions of RUSKII are operational. Each language dictionary, consisting of approximately 17,500 terms, is contained on an independent diskette operated by the same 2.0 operating program diskette. That is, an operational RUSKII set consists of two diskettes: a program diskette and interchangeable language diskettes. Furthermore, a "4-Pack" has been developed in which an improved RUSKII version 3.0 operating program has been combined with a 4-language menu-driven set onto a 10-megabyte Bernoulli cartridge for ease of storage, transfer, and use. The RUSKII "4-Pack" is also transferable to computer hard-disk storage.

Although the RUSKII program was designed primarily for internal use, there seemed to be much interest outside the center in what FSTC was trying to accomplish, namely to develop and distribute a simple personal-computerized language translation "catalyst." In view of this interest, a decision was made to officially offer RUSKII to U.S. government agency users by disclosing the availability of RUSKII in open military publications. Accordingly, two announcements of RUSKII were printed, the first in the October-December 1986 issue of *Military Intelligence* and the second in the February 1987 issue of *Military Review*.

As a result of these announcements, FSTC received over 100 letters of request for RUSKII in just over 100 days. A request rate of one per day for approximately three months indicated not only the extent of interest, but more importantly the size of the capability gap that we were endeavoring to fill. Even now, several written requests for RUSKII are received each week.

Operation

RUSKII operates in a word-by-word translation mode through a menu-driven format using an expandable language data base. Use of RUSKII for French, German, and Spanish is straightforward in that computer keyboard entry is generally accomplished in a manner similar to entry of English. In the case of Russian, entry can be made by utilizing either a transliterated keyboard or a software mode that converts a standard computer keyboard to Cyrillic. For example, Figure 1 shows

RUSKII in a ready-to-operate condition.

In order to "decipher" the title of an article, as shown in Figure 1, Russian terms are converted to English by the transliteration system shown in Figure 2. Upon entry, the RUSKII program can tell us that the first word, "nazemnaya," is translated "ground." The second word, "navigatsionnaya" is "navigation." The third word, "apparatura," is "device."

As illustrated in Figure 3, a printout (or screen display) of the article title indicates that the Russian article is about a "ground navigation device" — in this case, a system that is probably used on tanks.

After completing an examination of a Russian article title, a RUSKII user has the option of continuing the translation, forwarding the article for a professional translation, or discarding the article. The entire process requires less than five minutes.

Conclusion

The wide availability of personal computers in the last several years has afforded cost-effective efficiencies previously unobtainable. In terms of translating languages, one can envision future translation systems that are not only compact, but also based on optical or acoustical entry and output. This capability would have not only military utility, but civilian utility as well. Relatively simple systems such as RUSKII are perhaps a first step in this direction.

In this article, we have reported on the development process, capabilities, and limitations of an original software package created at the Foreign Science and Technology Center, Charlottesville, VA. Clearly, it is has been observed that a sizable requirement now exists in the field for a computerized "catalytic" means of language translation. Through the development of RUSKII, FSTC has made a first effort to bring a non-dedicated automated language capability to personal computer users.

NOTE: RUSKII is for Official Use Only, distribution is limited to U.S. government Agencies Only.

Special thanks is extended to University of Virginia students Michael Bittner, Elizabeth Gauger, Alex Kekesi, Reed MacMillan, Joanne McKeown, Pam McNab, Linda Papst, Dave Van Harlingen, and Cindy Yetter-Vassot. Their efforts were instrumental in furthering the development of "RUSKII: A Language Translation Catalyst."

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Belvoir Provides Support for PATRIOT

A tremendous amount of manpower and talent has been expended from development through the deployment stages of the PATRIOT Missile system. The Army's Belvoir Research, Development and Engineering Center (BRDEC) has been and remains a major part of this team effort. The Special Projects Team (formerly PATRIOT Project Office) of BRDEC's Logistics Support Directorate is the responsible element supporting the PATRIOT program.

BRDEC provided the technical expertise in the design, development and production of electric power plants (AN/MJQ-24), electric power units (PU-789/M), 150kW gas turbine generator sets, a split package 18,000 BTU air conditioner and an application kit for the launcher generator set. Included in this effort was the development of technical data packages (TDP) that allow competitive procurement.

Prototype models of the AN/MJQ-24 and the PU-789/M were fabricated and assembled by the BRDEC's Model Fabrication Division. Engineering testing of these prototype models was conducted by BRDEC's Product Assurance and Engineering Directorate.

The AN/MJQ-24 provides 40 hertz electric power to the PATRIOT Engagement Control Station. The power plant is a self-contained system consisting of two 150kW turbine generator sets, a power distribution unit and two cable racks for storage of four 75 foot power cables and one 75 foot control cable. The unit is mounted on an M-942 5-ton truck chassis.

BRDEC designed, assembled and tested the first seven production units in-house for use in component design configuration/system design confirmation and field operation evaluation of the PATRIOT system as well as the training of key military personnel.

As the Belvoir units were being assembled, a production contract was negotiated utilizing the BRDEC developed TDP. To date, there have been two production contracts awarded, with delivery of the first one completed. The second contract is active with the contractor still delivering units.

The key component of the AN/MJQ-24 is the 150kW generator set. BRDEC provided the expertise to militarize a commercial Allison turbine generator set to meet PATRIOT's electric power requirements. The preprodution sets were subjected to extensive preproduction tests and early field testing of the PATRIOT missile.

First article test sets have demonstrated a mean time between failure rate of 557 hours. BRDEC's TDP was utilized in the solicitation and recently awarded contract to Essex Electro Engineering Co. for the final buy-out of generator sets to meet the missile's deployment schedule for the AN/MJQ-24. These sets are scheduled for delivery in mid-1989.

An Infrastructure for International Armaments Cooperation

By COL Charles E. Gardner

Introduction

The presence of an international element within Headquarters, U.S. Army Materiel Command (AMC) is not something new but the emphasis on what this element does has increased significantly in recent months. Much of this renewed awareness started in July 1987 when the deputy commanding general for research, development and acquisition (DCGRDA) requested each AMC major subordinate command (MSC) to take a look at how they supported international activities.

In October 1987, the commanding general of AMC took a major step by "dual hatting" the DCGRDA as the deputy commanding general for international cooperative programs (DCGICP) and establishing an Office for International Cooperative Programs. The office was formed from elements of the U.S. Army Security Affairs Command (USASAC) and the Test and Evaluation Command (TECOM).

While HQ, AMC has had a similar structure in the past, this is the first time that the international community has been linked throughout AMC to include; the areas of co-production and foreign military sales elements within USASAC, the assistant secretary of the Army for research, development and acquisition and the Army acquisition executive, and the deputy under secretaries of Defense for international programs and technology and test and evaluation.

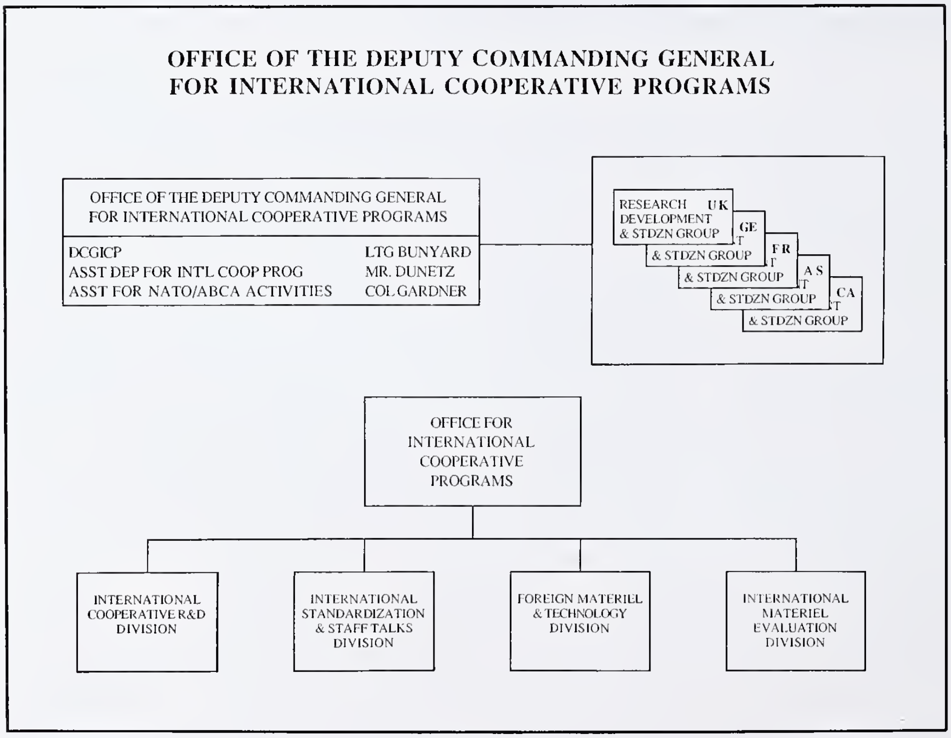

Figure 1.

The Past. . .

Historically, one must go back about a decade to examine the current impetus for armaments cooperation although General Eisenhower and Field Marshall Montgomery clearly recognized the importance of armaments cooperation and put in place the nucleus for the American, British, Canadian, and Australian (ABCA) Armies Standardization Program immediately after World War II.

The Culver-Nunn Amendment to the FY77 Defense Appropriations Act directed that the Services should standardize where possible but as a minimum become interoperable with the NATO Allies. This effort within NATO became known as rationalization, standardization and interoperability (RSI). RSI focused heavily on armaments cooperation as well as harmonization of procedures, tactics, doctrine and training which continues today. Armaments cooperation, because of economic factors, loss of jobs, national pride, incompatible technical specifications and "not invented here," proved to be most difficult.

Nevertheless, there are certain "hardware-based" issues which cannot be ignored such as bullets/projectiles fitting guns, interoperability of combat net radios, and compatibility of consumables/fuels. The joint chiefs of staff told the Services which areas were important many years ago and certainly NATO has spent exhaustive efforts attempting to attain and maintain certain capabilities. So, we see there is very little new here.

The Present. . .

What is new here is the organization and management methodology which AMC has put in place to facilitate this process. This facilitation process includes the management and staff oversight of numerous ongoing programs as well as establishing and maintaining a good interface with the U.S. Army Training and Doctrine Command (TRADOC), the Department of the Army (HQDA) and the Office of the Secretary of Defense (OSD).

The structure of the Office of the Deputy Commanding General for International Cooperative Programs is shown in Figure 1. Note that the standardization representatives in five countries report directly to the DCGICP as well as an internal Office for International Cooperative Programs which is headed by a colonel. A listing of the specific programs associated with armaments cooperation is shown in Figure 2.

The office operates within a large matrix organization in that all of the tasks associated with these programs are executed by the AMC MSCs, the program executive officers (PEOs)/project managers (PMs) or TRADOC centers and schools that provide the subject matter experts to prepare the U.S. Army position.

The office concentrates much of its efforts in the development of policy, regulations, procedures, handbooks, and orchestration of the entire process. While armaments cooperation has proven to be a difficult challenge, the benefits of this cooperation can be seen in the growing government-to-government and industry-to-industry contacts and activity within the international arena. Recent efforts on Mobile Subscriber Equipment, the Forward Area Air Defense Systems and 155mm Howitzer/Ammunition serve to emphasize the point.

In practice, armaments cooperation spans a vast network of structured and unstructured contacts among OSD, DA and AMC personnel and their foreign counterparts working through government and industry contacts and formalized arrangements such as NATO, ABCA or the Bilateral Staff Talks. This network begins at the basic research level with interfaces such as the contracts let by the European Research Office in London or participation in NATO or other research information exchanges. It proceeds through complex arrangements for data exchange in specific technical areas in accordance with national disclosure policy. It may involve actual exchanges of personnel under a memorandum of understanding or the Scientists and Engineers Exchange Program or it could evolve from a nondevelopmental approach under the Foreign Weapons Evaluation Program, the NATO Comparative Test Program or an initiative by a PEO or PM.

ACTIVITIES

COOPERATIVE VENTURES

- Cooperative R&D
- MOUs
- Tech Cooperation

FORMAL EXCHANGES

- Defense Data Exchange
- Scientist/Engr Exchange
- Defense Dev Sharing (CA)
- Bilateral Staff Talks
- Systems & Tech Forum (JA)
- Tech Coop Committee (KO)
- TTCP (ABCA Countries)

MATERIEL TEST & EVAL

- NATO Comparative Test
- Int'l Matl Evaluation
- Reciprocal Use of Matl
- Developer Testing

STANDARDIZATION

- NATO Panels/WPs
- ABCA QWGs
- STANAGs/QSTAGs
- Air/Naval Stds
- STAN Groups
- LOG Interoperability
- Army Ofc of Record
- Implementation/Eval

TECHNOLOGY ASSESSMENTS

- NATO Coop R&D
- AGARD
- Defense Research Gp Emerging Technology
- Concept Evaluations
- Scientific/Tech Surveys (STAN Gp Reports, STCEUR/STCFE, Trip Papers)

ACQUISITION MANAGEMENT

- Market Surveys
- Market Investigation
- Int'l Data Base
- RSI Plans
- Coop Opportunities Plan
- Decision Reviews

INTERNATIONAL COOPERATIVE PROGRAMS

Figure 2.

There is no single prescribed method to achieve international cooperation — getting both parties to agree on a common objective and a willingness to share the burdens and benefits is 90 percent of the challenge. Whatever the approach, the objective remains the same — to provide the U.S. soldier with the best available equipment, at the lowest reasonable cost and in the shortest period of time.

The Future. . .

The long term trend for international armaments cooperation is definitely upward. This is driven mainly by the pressures of reduced defense spending, a common threat, and economic necessity for independent industrialized nations to acquire advanced technology and share available free world defense markets.

For the Army and its Army Materiel Command, this implies greater understanding and commitment to the ideas and objectives of defense cooperation in armaments. The international office has and will continue to develop the tools of this business by way of policy and procedures. "How to" handbooks on international cooperation will be available to organizations responsible for program execution. Also, recurring workshops, which address specific aspects of programs, will continue as a proven method of addressing issues and changing procedures.

The establishment of a new and improved organizational infrastructure within AMC headquarters and the major subordinate commands and agencies will allow the Army to reap the benefits of increased armaments cooperation.

COL CHARLES E. GARDNER is chief, Office for International Cooperative Programs and the assistant for NATO/ABCA activities. He received a bachelor's degree in engineering from the U.S. Naval Academy in 1961 and holds an M.S. degree in civil engineering from the University of Illinois. He is also a registered professional engineer in Virginia and California.

TACOM Seeks Improved Vehicle Crew Environment

By George Taylor III

If you have ever spent an entire day or night stranded in your car on a freeway in a snowstorm, you probably remember all too well the boredom, fatigue and stiffness that occur under such circumstances.

Fortunately for most of us, such a scenario is not a common one. But under certain battlefield conditions, combat vehicle crew members may be required to remain in their vehicles for hours or even days to ensure their safety.

At the U.S. Army Tank-Automotive Command's Research, Development and Engineering Center, engineers in the Vehicle Nuclear, Biological and Chemical Office are working with the California-based INVOTEC Conceptual Designs Co. to find ways of allowing combat vehicle crews to fulfill physiological and psychological needs while inside their vehicles for up to 72 continuous hours.

"Historically, troops have left their vehicles to find a suitable place to accomplish the restorative actions of sleeping, eating, exercising and relieving the stress associated with a battlefield environment," explained RDE Center engineer Mohsin Singapore. "But as time passes, the potential threat of the presence of an NBC environment on the battlefield is growing. Thus, ways will need to be found to permit crews to remain inside their vehicles for extended periods."

Singapore said that engineers conducted two tests in 1986 — one at Fort Knox, KY, and the other at Fort Benning, GA — in which volunteers were subjected to long periods of confinement in combat vehicles. He said the tests revealed that there were major adverse affects after 16 to 20 hours of confinement.

The results of these tests enabled INVOTEC to understand the problems resulting from prolonged confinement, and the firm subsequently proposed several sleeping/resting hardware items for use in combat vehicles. These include:

- sling harness — a lightweight sleeping/resting support net;
- modular pads — individual cushions that could be assembled into a variety of interconnecting multiple configurations with other pads and with the sling harness for body comfort;
- extendible bar — a roof-mounted vertical bar for use as a back support for the sling harness, a hanger for a commander's head-out seat for open-hatch operations and as an exercise bar;
- exercise device — an elastic cord assembly combined with the extendible bar that would enable the user to exercise each of the major muscle groups;

Crew member occupying sling harness in M1 tank.

- message device — a battery-powered unit that could be used alone or with a rolled modular pad; and
- relaxation/sleep conditioning program audio cassette tapes — tapes containing at least three types of programs: a self-teaching guide for exercise and muscle relaxation; self-suggested sleep-inducing imagery; and personally selected audio relaxing aids such as music.

The INVOTEC proposal came in response to a TACOM Small-Business Innovation Research (SBIR) solicitation asking for the development of equipment that would provide simple solutions to the vehicle confinement problem.

The small business program was initiated by Congress in 1983 to help out small businesses. Under its terms, federal agencies with R&D budgets of $100 million or more must award at least 1.25 percent of their R&D contracts to small businesses.

The INVOTEC proposal was selected by TACOM from 10 submitted in response to the SBIR solicitation as having the greatest potential. In August 1986, TACOM awarded the firm a Phase I contract to build and demonstrate concept hardware which could be adapted to currently fielded vehicles.

That effort was completed in February 1987 and, according to Singapore, efforts are now under way to get funding approved for a Phase II contract for INVOTEC to build additional sling harness/modular pad prototypes for use in field tests.

GEORGE TAYLOR III is a technical writer-editor for the Army Tank-Automotive Command. He hold's a bachelor's degree in journalism and a master's degree in communications form Michigan State University.

Conferences & Symposia . . .

Upcoming Conferences

- Seventh Annual Mobilization Conference of the Industrial College of the Armed Forces, in cooperation with the National Defense University's Mobilization Concepts Development Center, April 14-15, 1988, Fort McNair, Washington, DC. Additional information available by calling AV 335-1953 or Commercial (202) 475-1953.
- National Convention of the Army Aviation Association of America, April 13-17, 1988, Cervantes Convention Center, St. Louis, MO. Contact AAAA, 49 Richmondville Ave, Westport, CT 06880-2000. Telepone Bill Harris on (203) 226-8184.

Letters

Composites Technology

To the Editor:

I wish to correct an overly positive report of our efforts in the area of composite field repair which appeared near the end of the article on Composites Technology in the September-October 1987 issue of *Army RD&A Bulletin*. It is true that we have been working on the development of a self-contained kit for field repair of composites. However, for good and sufficient reasons, these efforts have not reached the stage where a useable kit has been produced.

I am convinced that our concept is valid and would be happy to discuss it with anyone with an interest in the area. A description of our work to date appears in MTL TR 86-23 which I would be pleased to provide to anyone requesting it.

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Nuclear Magnetic Resonance

To the Editor:

Recently, I read a featured article in the November-December issue the *Army RD&A Bulletin* by Hilary J. Winiger entitled "Nuclear Magnetic Resonance." Within this article, Ms. Winiger states that "MTL's system is the only one of its kind in the Army. . . .". To my knowledge, this statement is correct for nuclear magnetic resonance (NMR) spectroscopy of solids. However, there is at least one other high resolution, superconducting, pulsed NMR spectrometer within Army R&D. The Letterman Army Institute of Research (LAIR) on the Presidio of San Francisco utilizes the myriad of capabilities of its Varian XL-300 NMR spectrometer. This instrument, designed primarily for performing chemical analysis of liquid materials or dissolved solids, operates at a frequency of 300 MHz for protons, a full 50 percent higher than the spectrometer at MTL. This higher operating frequency is a result of the 7.05 Tesla superconducting magnet at the heart of the system. This leads to a considerably higher sensitivity and the ability to resolve chemical structures which have greater similarity. Moreover, the system at LAIR has multinuclear capabilities permitting the investigation of more than 60 different atomic nuclei possessing magnetic properties. The more common of these elements are hydrogen, deuterium, carbon 13, phosphorous 31, fluorine 19, sodium 23, and nitrogen 15.

The LAIR is one of seven laboratories within the Army Medical Research and Development Command (MRDC). Our motto, "Research for the Soldier," embodies a spirit which is shared by all workers throughout the command who are engaged in manifold research and development activities.

If requested, I would be pleased to author a short feature on the research activities in NMR spectroscopy at LAIR. Perhaps most noteworthy among these research efforts is that work in which NMR spectroscopy is being used as a noninvasive, nondestructive tool to study organ function, tissue viability, and cell metabolism in living animals.

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